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THE HAWAIIAN PLANTERS' RECORD

Volume XXIV. JANUARY, 1921 Number 1

A monthly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

Sugar Prices for 1918, 1919 and 1920.

The "Record" formerly published in each issue the sugar prices for a period of one month prior to the time of going to press.

During 1918 when the price of sugar was under governmental supervision, there being no fluctuations to report from month to month, the practice of reporting prices was discontinued.

We have been asked to resume the publication of sugar prices. The last quotation we gave was that of November 14, 1918, 6.055 cents per pound or $120.10 per ton.

The Food Control Act became effective August 10, 1917. It contained no provision for price fixing of sugar. The price of sugar was controlled, however, by the Food Administrator through voluntary cooperation of the various producers

Agreements in this connection began with beet sugar producers in August, 1917. Other arrangements were made with the Louisiana producers. In December the price was fixed at 6.005 cents per pound by the direct purchase of the whole 1917-18 crop of Cuba by the International Sugar Committee, this price applying to Hawaiian sugars January 2, 1918. On June 24, 1918, the price was raised to 6.055 cents owing to the increased cost of war risk insurance.

Beginning with the new crop, December 22, 1918, the price was advanced to 7.28 cents per pound for Hawaiian sugars. This price remained unchanged throughout the year 1919.

With the return to open market conditions in 1920, Hawaiian sugar began with the price of 12.29 cents on January 5, 1920. The highest price of the year, 23.57 cents, was reached May 19, and the lowest, 4.63, on December 14.

The prices applying to Hawaiian raw sugar are here shown in detail for the years 1918, 1919, and 1920, with the date of each fluctuation:

1918	per lb.	per ton
	96° Centrifugals	
Jan. 2*	6.005¢	$120.10
June 24	6.055	121.10
Dec. 22	7.28	145.60
1919		
No change from the quotation of Dec. 22, 1918.		
1920		
Jan. 5	12.29¢	$245.80
" 6	12.04	240.80
" 7	12.915	258.30
" 10	13.04	260.80
Feb. 5	12.79	255.80
" 7	12.54	250.80
" 9	12.165	243.30
" 16	11.03	220.60
" 26	10.28	205.60
Mar. 2	11.29	225.80
" 3	11.54	230.80
" 9	11.03	220.60
" 12	11.29	225.80
" 15	11.54	230.80
" 17	11.79	235.80
" 18	12.04	240.80
" 19	12.415	248.30
" 20	12.54	250.80
" 22	12.79	255.80
" 27	12.915	258.30
" 29	13.04	260.80
April 5	15.30	306.00
" 10	17.43	348.60
" 14	18.56	371.20
" 16	19.185	383.70
" 17	19.56	391.20
May 13	21.06	421.20
" 14	21.57	431.40
" 17	22.57	451.40
" 18	23.07	461.40
" 19	23.57	471.40
" 26	22.57	451.40
" 27	20.56	411.20
June 3	20.31	406.20
" 7	20.06	401.20
" 16	19.685	393.70

*The previous fluctuation was December 28, 1917, when the price changed from 6.0025¢ to 6.00¢.

"	17	19.56	391.20
"	29	18.31	366.20
July	6	18.56	371.20
"	16	18.31	366.20
"	20	17.81	356.20
"	21	16.80	336.00
"	26	16.30	326.00
Aug.	9	15.80	316.00
"	12	13.04	260.80
"	19	12.04	240.80
Sept.	13	10.78	215.60
Oct.	6	8.78	175.60
"	15	8.03	160.60
"	26	8.26	165.20
"	27	8.485	169.70
"	29	8.39	167.80
"	30	8.145	162.90
Nov.	3	8.01	160.20
"	5	7.515	150.30
"	9	7.265	145.30
"	10	7.02	140.40
"	11	7.015	140.30
"	12	6.64	132.80
"	13	6.51	130.20
"	15	6.515	130.30
"	16	6.52	130.40
"	18	6.26	125.20
"	19	5.955	119.10
"	22	5.76	115.20
"	23	5.77	115.40
"	26	5.76	115.20
Dec.	3	5.77	115.40
"	7	5.51	110.20
"	8	5.32	106.40
"	10	5.01	100.20
"	13	4.76	95.20
"	14	4.63	92.60
"	18	5.01	100.20
"	21	5.14	102.80
"	22	5.38	107.60
"	23	5.426	108.52
"	27	5.31	106.20
"	28	5.32	106.40

H. P. A.

Some Fundamental Requirements of Plants.*

By A. L. Dean.

The objects of the universe around us fall naturally into two great groups—the living and the non-living. The living organisms are distinguished by at least three characteristics: their capacity for growth whereby forms resembling the parents are built up through incorporation of materials contained in food, the capacity for reproduction, and the power of response to stimuli. With all the wide dissimilarities between the many forms of living organisms, there run through the whole series similarities in requirements. We find with all of them a sensitiveness to certain physical factors of their environment, of which temperature perhaps is the most important, a necessity for oxygen, for water and for food.

The different groups of plants and animals have developed along different lines in their solutions of the problems of securing these fundamental requirements. For example, we find that in a general way the plants secure their food supply by passive means, whereas the animals have developed powers of searching for food and for seizing it when they find it. It is an interesting study to compare the different types of plant and animal forms with the idea in view of noting how each has solved in some ingenious fashion the problem of securing its fundamentally important supplies.

Temperature.

Turning our attention to the higher plants and more especially the crop plants, we shall find a knowledge of their basic requirements is a starting point for the understanding of agricultural practice. Considering first the matter of temperature, we find plants to have a very wide vital range, running from just above the freezing point to about 120° F. In the range of temperature through which any given plant can function we can distinguish the minimum temperature as that lowest point at which life proceeds, the maximum temperature as the highest one which the plant can survive, and the optimum temperature as that best suited for its life processes. If we look into the matter a bit closer we shall find that these points are not the same for each of the different functions of the plant; that, for example, the temperature at which photosynthesis goes on to the best advantage is not likely to be the one at which respiration is the most active.

Plants resemble the group of the cold-blooded animals much more closely than they do the warm-blooded animals. With these latter we find that the tissues of the body are able to live only within a very narrow range. In the case of our own bodies we know that a slight rise above the normal temperature means fever and a slight falling below is a danger signal of failing vitality. We have developed an elaborate system for maintaining the temperature of the body tissues within very narrow limits so that, although taking our bodies as a whole we can

* A lecture given at the Short Course for Plantation Men, University of Hawaii, October, 1920.

endure great changes in the surrounding temperature, these changes are not communicated to the interior of our bodies to any notable degree, and if they are so communicated, death follows. In the case of the plants and the cold-blooded animals on the other hand, the temperature of the tissues of the organism tends to follow that of the surroundings. Some regulation of temperature there is, but it is slight indeed compared with the elaborate machinery and great accuracy of adjustment of the warm-bodied animals.

The plant has certain sources of heat, notably that which comes from within through the process of respiration, and that which comes from without in the form of the radiant energy from the sun. At the same time heat is being lost by transpiration which involves the evaporation of water and is especially active in the leaves, and by radiation from the whole surface of the plant body. The resultant of these more or less conflicting factors is a temperature within the plant which is commonly not the same as the temperature of the atmosphere, but on the other hand does not vary so very widely from it, nor is it maintained in any degree of uniformity. This means, of course, that the growth of the plant in so far as it is regulated by temperature is closely dependent upon the atmospheric conditions and that the effects of these cannot be overcome by variations in the food supply.

Oxygen.

Everyone recognizes that animals require oxygen and that the terrestrial animals get this from the air and the aquatic animals get it from the oxygen which is dissolved in the water. It is less commonly recognized that plants are likewise dependent upon a supply of oxygen and that this almost invariably is derived either directly or indirectly from the air. A few very lowly forms of plants belonging for the most part in the group of the bacteria do not require air, and, indeed, some of them have their growth hindered or stopped by its presence. With this minor exception, however, all plants are as dependent upon oxygen as are the animals. In the case of our crop plants we find that leaves are provided with an elaborate system for allowing air to enter and circulate and that a very substantial portion of the leaf tissue consists of air spaces. This inter-cellular space system in the leaves communicates with the outside atmosphere through numerous stomata or minute openings in the leaves' surfaces. With some plants these are found only on the under surfaces, with others on both under and upper surfaces. They vary greatly in number, but are exceedingly numerous in most plants. They are so constructed that they are capable of opening and closing with variations in the water supply of the plant. The stems of the herbaceous plants are also provided with stomata, although in much smaller numbers than the leaves. The stems of woody plants have a different mechanism for accomplishing this same process of aeration. With the roots we find that there are no openings for allowing air to enter, but that the oxygen is absorbed from solution in the soil water. This soil moisture in its turn must secure this dissolved oxygen through contact with air in the spaces of the soil, hence the necessity for a proper aeration of the soil and one of the chief reasons why densely-packed and waterlogged soils give such poorly-developed or diseased root systems. Although the highly developed aerating system of the leaves is required for another

purpose, as well as that of respiration, yet its importance in relation to this function cannot be overlooked. We find throughout the whole plant body that wherever there are actively living cells, there is the demand for oxygen which must be met by some contrivance or other. The amount of oxygen required by growing plants is often very large. With things which are growing actively, such, for example, as germinating seeds, the amount demanded will equal or exceed the amount required by man per unit of weight. With some of the microscopic forms which are reproducing with great rapidity an oxygen requirement as high as 200 times as much as that of man per unit weight has been recorded. This consumption of oxygen is directly related to the means of securing the energy required for carrying out the life processes.

It is difficult for us to realize that in the quiet and hidden processes of growth going on within the plant there is a demand for the expenditure of energy. We are accustomed to think of energy in its more evident and spectacular form. It is true, nevertheless, that these invisible processes are great consumers of energy, and it is just as true in the plant body as it is in the field of engineering that you cannot get energy except from some source which is supplied from the outside. In the case of plants as in that of animals the required energy is furnished through the oxidation of substances within the body by a process which we may call physiological combustion to distinguish it from the ordinary and violent form. Just as we must have air for the combustion of fuel in our furnace, so too we must have oxygen for the processes of oxidation, with their accompanying energy release, which are going on inside the plant and animal bodies.

It follows from these general considerations that wherever we have a living cell there we must have a supply of oxygen. The products which result for the most part from these processes are carbon dioxide and water, the ordinary oxidation products of carbon and hydrogen. We call this process whereby the potential energy of chemical compounds within the body is set free for physiological uses, respiration. Our ordinary notion of respiration is the process of drawing air in and out of the lungs of the higher animals. Even in the case of these animals, however, this is but the beginning and ending of a process. It is the drawing in of oxygen from the outside and the return of carbon dioxide gas and water vapor which have resulted from the utilization of this oxygen throughout the entire body. The true process of respiration is going on in all tissues; in the muscles, and glands, and nervous system; wherever, in short, there is active cell life. If we accustom ourselves to this view of respiration we shall see that it is equally appropriate to the analogous chemical processes which are going on in the plant body, even though we do not have the drawing in and expelling of gases by obvious muscular activity.

WATER.

Not only are all living organisms dependent upon oxygen derived either directly or indirectly from the atmosphere; they are also dependent upon an adequate supply of water. The actively living parts of plants and animals consist of water as their chief ingredient. The ordinary animal muscle is approximately 80% water, and the actively growing parts of plants, such as young roots

and leaves, are usually over 90% water. Of course, there are parts of animal bodies and parts of plant bodies which contain relatively small amounts, but these are the parts which are not actively growing, or which, like the bone, are designed for some special purpose where rigidity is the principal consideration.

Everyone knows that if a sufficient supply of water is cut off from a plant it will wilt. This wilting is due to the evaporation of the water away from the more tender parts of the plant without a sufficient supply being brought in to take its place. The firmness of the ordinary leaf and stem is due to the fact that all of the cells of which they are composed are stretched with water, and this mass of tightly-stretched cells has the firm, more or less rigid character of the healthy plant. Another important use of water in the plant is as a medium for entrance of the plant's food materials. We have already noted that the gases enter into the inter-cellular spaces of the aerial parts of plants through minute openings through which the gases can circulate. When they are in this inter-cellular space, however, they are not yet inside the cells. The gases which are used must dissolve in the moisture which saturates the cell walls adjacent to these inter-cellular spaces, and it is in the form of dissolved gases that they finally reach the actual living parts within.

When we examine the root systems of plants we find that they present an unbroken surface. There are no small mouths or openings through which the water of the soil with its dissolved nutrients can enter. Everything has to pass through the walls of the cells on the outside of the roots, and that means that everything passes dissolved in water. Thus the fertilizers which we use on the soil and the materials of the soil itself must first dissolve in the soil water and in the form of solution pass through the membranes of the roots and thence into the other parts of the plant. Not only do these food materials enter dissolved in water, but they move about the plant in solution, and the substances which the plant has itself elaborated, such, for example, as sugar, pass from one part of the plant to another dissolved in water.

There is an ascending current of water, carrying substances in solution, which rises from the roots to the leaves. The speed of this current varies greatly according to the kind of plant and the conditions under which it is growing. It may go a few inches per hour; it may go a number of feet. The water which rises in this current is evaporated from the leaf cells into the inter-cellular spaces and passes out through the stomata in the form of water vapor. This process by which the water evaporates from these cells and thence escapes to the outer air is called transpiration and the rising current of water from root to leaves is frequently spoken of as the transpiration current. The plant exercises some degree of control over this, since one of the first manifestations of insufficient supply of water will be the closing of the guard cells of the stomata. This cuts down the transpiration and tends to ward off the evil effects of the restricted water supply. But closing the stomata interferes with other processes besides that of transpiration and the whole vigor of the plant's growth is seriously handicapped.

One of the effects attendant upon this evaporation of water through leaves is the cooling due to the change of state from the liquid to gaseous water. This is undoubtedly an important matter when leaves are exposed to the light and heat of the tropics. Some plants are able to stand this high temperature without

serious injury, but others are only able to endure it when they have a bountiful supply of water for their root systems. If the process of transpiration is once stopped in these more tender plants and the leaves wilt, they never recover.

Our ordinary crop plants secure their entire water supply from the soil. It does not follow, however, that the soil with the most water in it is the most advantageous. If the water is present to the exclusion of air in the spaces between the soil particles, the plant will suffer from lack of oxygen. These terrestrial plants have adapted themselves to secure their water supply to best advantage when the soil is not waterlogged, but when the particles which make it up have each a film of water about it. The small rootlets and the minute root hairs with which most young roots are provided are in intimate contact with the particles of soil, so intimate, in fact, that when we uproot a plant and shake it, the rootlets do not appear naked, but have clinging to them coatings of these soil particles between which the roots have grown.

There are great differences in the water-holding capacity of different soils, differences due to the size of the soil particles and the proportion of decaying organic matter mixed with the mineral particles which have been derived from decomposing rocks. The reasons for many of our agricultural practices can be traced to the necessity of maintaining the proper conditions of air and water in the soil, conditions which are absolutely essential if we are to secure the vigorous growth which good agricultural practice calls for.

Physical Properties of Soils.*

By L. A. Henke.

A soil may be defined as a loose and friable material in which plants may and do find a foothold and nourishment as well as other conditions of growth.

Hawaiian soils come from two sources. They are either the results of volcanic eruption or coral growth on the edges of the volcanic islands which must have been formed first. A later upheaval after a coral reef had been formed around the islands could easily result in the coral limestone being brought far inland from the seashore, and a later volcanic eruption might easily cover up the coral reef formed on the fringe of the islands. Evidence abounds that both of these processes did take place, with the result that the lava and coral limestone soils are intimately mixed in many places.

Soil formation is essentially a process of big rocks becoming small due to various factors about to be discussed. Temperature changes play a big part in most parts of the world, although they may be of only minor importance in Hawaii because of our uniform climate. In regions of extreme temperatures and in the mountain peaks in the tropics rocks are continually being split asunder

* Summary of a lecture given at the Short Course for Plantation Men, University of Hawaii, October, 1920.

because the different parts of a complex rock do not expand or contract equally with temperature changes. This is well illustrated on the top of Pike's Peak, in Colorado, and to a lesser degree on the top of Haleakala, on Maui.

Water is a second big factor in breaking up rock particles in such small parts that we term them soils. Flowing water grinds rock particles against each other, and the soluble parts of the rock are dissolved out and deposited in lower regions or carried to the ocean. The cutting and grinding action of water is well illustrated by deep chasms found in our mountains, usually with a stream at the bottom of same, but every little stream that trickles down over a rock is doing exactly the same thing, but on a much smaller scale.

In some parts of the world winds are a big factor in soil formation and mixture. A strong wind will carry little particles of grit which blow against rocks, resulting in gradually cutting away the rock surface. Wind action is probably of little importance in Hawaii, but the "buttes" of Montana are striking monuments to the ability of strong winds to lower the surface of the land to a marked degree. The combined result of both water and wind is to lower the land surface and fill the ocean. Renewed unheavals of the land in various parts of the world from time to time, of course, add to the supply of land above the ocean level.

After rocks are somewhat broken up by the above agencies, or even before, the lowest forms of plant life begin to play a part in soil formation. Lichens will grow on a bare rock with only a little amount of moisture, and their roots secrete such a strong acid, that the rock surface on which they cling is partly dissolved, and mosses and later ferns begin to get a foothold in the rock where some plant food has been made available. Mosses and ferns die and decompose and add a new and vital substance to the soil which we call organic matter. In the decomposition of these plants carbon dioxide is formed and this combines with water to form carbonic acid, which still further dissolves the rock particles. In fact, carbon-dioxide is secreted by the roots of all growing plants, which makes it possible for roots to take plant food out of the soil which pure water could not dissolve. The gas oxygen also plays a big part in soil formation, by combining with parts of rocks to increase their volume, which usually results in splitting of the rock surrounding these oxidized parts.

The above brief description will indicate in a general way how soils are formed and how organic matter is incorporated with them. After they are formed they may remain in their place of origin, as the Wahiawa section on Oahu, in which case they are called residual soils. Or they may partially slide down a mountain side, collecting on the flat slopes, in which case the resultant soils are colluvial. Or they may be picked up by a stream of water flowing at high velocity and dropped out again when the stream decreases its velocity due to its approaching sea level. The fertile delta of the Mississippi river is formed in this way, and such soils are called alluvial.

When all the above has taken place we find that soils consist essentially of four things—rock particles of all sizes, organic matter in all stages of decomposition, water, and forms of life commonly called bacteria.

The rock particles range in size from particles so large that we call them gravel to minute pieces perhaps only 1/25,000 part of an inch in diameter. These

rock particles contain reserve plant food, and some of the plant food immediately available to plants. These rock particles constitute the skeleton or framework of the soil, for the balance of the soil is built around them.

The organic matter consists of the remains of plant and animal life in all stages of decomposition. It finally forms this black or dark-colored, sticky material in the soil that is termed humus. Under certain conditions, such as unusually high temperature, with too open a condition of the soil, organic matter will be completely oxidized, leaving nothing but the ash or mineral constituents behind, and no humus will be formed. This is especially likely to be the case in hot arid sections. In the rainfall sections of the United States it takes about six parts of organic matter to make one part of humus, but in the arid sections of the West it takes twenty parts. It is rather hard to draw a distinct line between organic matter and humus, but for general purposes it may be assumed that when organic matter has decomposed sufficiently so that it is impossible to tell what is was originally, it may be termed humus.

Humus is of great importance in the soil. It coats the rock particles, holding them apart and also cementing them together. Humus contains much of the soil nitrogen, and the ash constituents of the plants or animals from which it is derived. It undoubtedly is a big factor in holding applied fertilizers till the roots of plants can absorb same. Humus holds much of the soil moisture, affects the temperature of soils by making them warmer, gives soils their dark color, absorbs gases, and is of vital importance in providing food material for the bacteria in the soil.

The water content of a soil varies from a few per cent in the case of sands to fifty or more per cent in the case of soils with much organic matter. Half the water-holding capacity of a soil is usually considered most favorable for the growth of plants. The water in soils that is of most use to plants is known as capillary moisture and is held in a film around the soil particles, and always tends to distribute itself equally through the soil by traveling from particle to particle, as coffee travels through a cube of sugar.

Life Conditions in the Soil.*

By L. A. Henke.

Productive soil teems with living organisms which eventually return their bodies to be incorporated in the soil in the form of humus and ash. Among living animals or organisms which spend part or all of their life in the soil may be mentioned burrowing animals, earthworms, ants and insects, molds and fungi and bacteria.

While burrowing animals give the greatest evidence of their presence, they

* Summary of a lecture given at the Short Course for Plantation Men, University of Hawaii, October, 1920.

probably benefit the soil least of any of the life forms found there, because they are usually not very abundant, and if they were abundant they would prove such a nuisance in most respects that we would employ all means available to get rid of them.

Earthworms, however, are of real value in the soil. They loosen, aerate and drain the soil below the plowing depth, and annually pass enough soil through their bodies to leave castings to a depth of about one-fifth inch over the soil surface, if all the work were done in one night so that the combined results could be seen. Darwin says that there are about 25,000 earthworms in an acre of average soil, and that the castings resulting from the soil passing through their bodies make the best kind of fertilizer. Earthworms are found only in soils abundantly supplied with humus, and they can not stand flooding. They live largely on organic matter which they take out of the soil, but inorganic plant food in the soil is made available by the digestive juices of the worm.

Ants and insects spend part of their life cycle in the soil, which results in their bringing much very fine material to the surface each year. Insects which are very destructive to many plants may thus exercise a beneficial influence while they are in the soil.

Fungi and molds are forms of life with a thread-like growth which secure food material from living and dead organic matter in the soil. They are big factors in distributing organic matter and humus through the soil mass.

Germs or bacteria are undoubtedly the most important forms of life found in the soil. They may be helpful, harmful or harmless. They range in numbers from about 50,000 per gram in sandy soil to several million per gram in a rich garden soil. They are most abundant in the first few inches of surface soil, near, but not at the surface. Not many bacteria are found below a two-foot depth, but this will depend largely on the openness of the soil. The best crop yields are usually obtained on soils abundantly supplied with bacteria.

Bacteria need organic matter for their food, and the presence of this determines their abundance. They will live in a wide range of temperatures, but a rather warm soil with optimum moisture content for crop growth is also best for them. The vast majority of bacteria require a slight alkaline reaction in the soil, and practically none thrive in a soil that is distinctly acid.

Bacteria are vitally concerned with the nitrogen supply of soils. One class known as the nitrogen-gathering bacteria live on the roots of legumes and, working through the stems and leaves of leguminous plants, take nitrogen out of the air and add it to the soil. Neither legumes nor the bacteria alone can take nitrogen out of the air, but when the two are working together they accomplish this interesting process. There are specific bacteria for each kind of legume, but practically all of them require the same soil conditions—non-acid soil and good drainage. When the bacteria are not present in the soil they can be introduced at the same time that the legume is planted.

Nitrifying bacteria convert nitrogen in the organic form to nitrates—a form that the roots of plants can absorb. Decaying vegetable matter contains its nitrogen in the organic form, and this nitrogen is of no use to succeeding crops till the nitrifying bacteria have converted it into an available form to be absorbed by the roots of plants. These bacteria require an open warm soil for their best

growth and work, and in a warm place like Hawaii they convert organic matter into nitrates very rapidly. Nitrates are soluble and may be leached out of the soil before a succeeding crop can absorb them.

De-nitrifying bacteria belong to the harmful class, because they reduce nitrates to nitrites and eventually gaseous nitrogen, which escapes into the air and is thus absolutely lost to the plants. In general, they are found under conditions that are opposite to those favorable for nitrifying bacteria. They do not need free oxygen and consequently are often abundant in poorly-drained soils. They are generally found in large numbers in fresh horse manure, and if fresh horse manure is applied together with a nitrate fertilizer it may result in the waste of expensive nitrogen fertilizer.

Some soils contain a type of bacteria that can fix nitrogen in the soil independently of legumes, but the amount of nitrogen they add is so small that they are only of minor importance. Bacteria that are responsible for many plant diseases are also found in the soil, but this introduces a big subject which should be treated as a separate topic.

After-War Sugar Prices*

By Romanzo Adams.

Under modern conditions of production and commerce a great war is sure to create profound disturbances in business relations. Sources of supply are cut off. New demands appear or, maybe, old demands are suddenly destroyed. Some sorts of production need to be speeded up, others need to be reduced, and still others must be reassured and made steady. Prices, if left to the free play of competition, are characterized by an extreme degree of fluctuation, and the fluctuations may be erratic—not corresponding to the fundamental conditions of supply and demand, but to the state of mind of the people, which may be optimistic one week, panicky the next, and ill-informed all the time. Some of the facts essential to the exercise of sound judgment are pretty sure to be concealed in war time. The extreme fluctuations in price do not guide production in the right way just because they are erratic. For example, copper production should have been put on a capacity basis in September, 1914, but prices were reduced and half the men in copper mines were laid off.

For this reason the governments of nations at war commonly undertake to regulate the prices of certain commodities by legal procedure and to control production of some means other than competitive prices. The need for such regulation and control continues after the war until considerable progress toward economic reconstruction has been made. The return of an industry from governmently controlled prices to a state of competitive control is more difficult than

* From a lecture given at the Short Course for Plantation Men, University of Hawaii, October, 1920.

the opposite procedure and calls for a profound understanding of business conditions.

The war control of sugar prices was pretty successful. Consumers were able to secure a fair supply at reasonable prices—prices high enough to encourage a steady increase in production in nearly all regions outside of Europe. These were the proper ends to be achieved. The return of price control to the forces of competition was not well timed or skilfully performed, and herein lies the secret of the erratic behavior of sugar in 1920.

A year ago, while we were still too near to the war and its immediate consequences to permit of an accurate estimate of world demand, sugar was turned over to the forces of competition except for some ineffective-for-good and unwisely used power in the hands of the Attorney General. It was known that there was a poor crop in Louisiana and that beet sugar production was below that of the preceding year. There was an exaggeration of Cuba's decrease in production. It was known that Europe's production was far below normal. Prohibition was expected to result in a marked increase in the use of sugar for soft drinks and candy in the United States. All these facts and supposed facts supported a forecast of high prices. The inflation of money and bank credit which occurred during the fall and early winter months was an influence in the same direction. Europe's early buying in Cuba was a factor. Added to all these price-raising factors was the state of the public mind. We had witnessed rising prices for so long a time that rising prices seemed natural. Factors tending toward low prices received scant consideration. Far too little weight was given to the reduction of Europe's demand because of lack of purchasing power. Little or no allowance was made for the Federal Reserve Board's announced deflation policy. While the mind of the business public was in this mood the Attorney General approved of seventeen cents for Louisiana sugar, apparently to save the planters from loss on account of a partial crop failure. Then canners and other sugar users became nervous and bought heavily to be sure of supplies. Refiners and jobbers usually buy heavily on a rising market, and so do many retailers. Of course, there were some irregular speculators. And while prices were at the top the writers in sugar trade journals were telling us that the prices were justified by fundamental conditions. The trouble arose from the fact that nobody knew the essential conditions. The competitive machinery had been out of use too long a time, and it failed to reflect fundamental conditions. At this distance it appears that there was little or no real sugar shortage so far as the United States was concerned. The Department of Agriculture has estimated recently that when prices were about at their highest there was an excess of sugar above the usual stock at that date of about thirteen pounds per capita—about one-seventh of a year's supply. The high price of sugar was due mainly to a series of mistakes and miscalculations.

One of the sources of miscalculation is worthy of a little further attention. There is no well-organized sugar market for speculation like there is for wheat and for cotton. Speculative buying of wheat is distinguished from millers' demand. What the speculator buys will come back into the market after awhile. What the miller buys is out for good. Now, since sugar had no regular speculator's market, most of the speculation being in the hands of refiners, jobbers,

grocers, and irregular speculators whose operations were not in the open, the speculator's demand was supposed to be a consumer's demand. We were regaled with accounts of the remarkable increase in sugar consumption when the sugar was only going into temporary hiding to appear later to help drive the prices down. An open market for sugar speculation would have prevented this mistake.

As long as prices are subject to the erratic after-war influences one can not forecast the future with a high degree of confidence. Who, a year ago, would have predicted for sugar or for coal the price fluctuations of 1920? Still, we need not give up altogether. Now that coal and sugar have had their fling, perhaps they will settle down to a more steady, and so a more predictable performance.

Apparently sugar prices for 1921 will be low—low in comparison with other commodity prices, low in comparison with the expenses of producing the crop. Much old crop sugar is still on hand. Beet sugar production in the United States is estimated at about forty per cent above last year's crop, and that of Europe is expected to show a thirty per cent increase. The acreage in cane has been increased in many regions, especially in districts where it has not been produced on a very large scale. Crop prospects seem to be fair. Probably Europe's increased production will be matched by her growing purchasing power. America will be able to secure abundant supplies at low prices.

If a moderate reduction in the price of sugar would stimulate consumption notably we might anticipate a marked increase in the American demand. But such is not the case. Sugar consumption is largely a matter of habit in America and is not much affected by considerations of economy. Barring unexpected deficiencies in production, this means lower prices.

There will be need for the speculator to carry over some of the 1920-21 crop to the next year. But speculators will not repeat the mistake of 1920. An opposite mistake is more probable. Refiners, jobbers, speculators, merchants, and housewives will carry low stocks in anticipation of still lower prices, and this will help to reduce the price.

If the above analysis for 1920-21 is correct there will be a diminished production in the following year and a consequent increase of price. In this readjustment of supply the beet sugar grower will take a more active part than the producer of cane. Good beetroot land is good land for corn, wheat, alfalfa, or other crops. Beet growing is carried on in connection with mixed farming, and little specialized equipment is needed, so that if the farmers are not satisfied with beet prices they turn easily to other crops.

In case the world achieves a condition of stable peace we may expect a gradual reduction of price fluctuations, and in two or three years the more permanent price influences will take control of the situation.

Report of the Committee on Milling.*

By Robt. E. Hughes.

As chairman of the Committee on Milling, I respectfully submit the following report:

I addressed letters and enclosed a list of questions to thirty mill engineers and received but six replies, which are incorporated in this report.

Since our last convention, held here in Honolulu in 1917, the developments and improvements in milling machinery have been forging ahead at a good rate, and so the increase in extraction, decrease in per cent moisture in the final bagasse, and general increase in efficiency, of all that has to do with the manufacture of sugar in the Islands is clearly shown by the records established in the milling plants.

Changes and improvements have been made at many stations throughout the mills.

The steel cane conveyor slat has proven beyond a doubt its superiority over all others by its continued good work wherever installed. Other improvements at the carriers, are the replacement with chain of the steel roller type, and the deepening of the carrier pits at the unloading stations.

Mr. Geo. Duncan, of Olaa Sugar Co., reports the following on Carriers:

"The only improvement made to the cane carrier is the substitution of steel slats for the wooden ones. The carrier is far cleaner underneath, and the stops to change broken slats are practically eliminated."

Mr. Geo. Crook, of Pioneer Mill Co., has the following to report on Carriers:

"We installed the Link Belt conveyor chain No. SS96, and corrugated slats last year. The chief advantage is less trouble with chain, slats, and bolts coming loose due to trash and cane cutting from the knives collecting in the links of the old class of chain and slat. There is less cleaning up to do in the cane carrier pit, and a saving of small cane in a season's run."

Mr. O. Olsen, of Lihue Mill, has the following to report on Carriers:

"The cane carrier was lowered last year, so that there is a drop of about eight feet from the cars."

The Puunene Mill reports the installation of the Link Belt No. SS96 bushed steel roller type chain, with the overlapping flat steel slat in Mill "B."

This chain is arranged to run on a steel rail, with guide bars of angle iron, so that the weight of cane on the carrier is not taken up by the chain; the chain being used merely to draw the load along.

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* Presented at Eighteenth Annual Meeting of the Hawaiian Chemists' Association, held jointly with the Hawaiian Engineering Association, November, 1920.

Unloaders.

There is nothing new to report on unloading machinery, other than the gradual increase in installations of the Wicks type of unloader.

In the writer's opinion, all mills should be equipped with two unloading machines to a carrier, so that delays at this station will be positively eliminated.

The installation and upkeep costs of any of the three rake types of unloaders, namely, the Wicks, Bossee, and Ogg, are so low, that an extra machine will more than pay for itself in a season's run.

Revolving Knives.

At a recent visit with Mr. A. F. Ewart, of the Honolulu Iron Works, the writer was shown sketches of a new type of knife and shaft that is to be built and installed in the Waialua mill.

Mr. Ewart has kindly consented to include the prints in this report, and writes the following:

Improved Method of Attaching Knives in Revolving Cane Cutters.

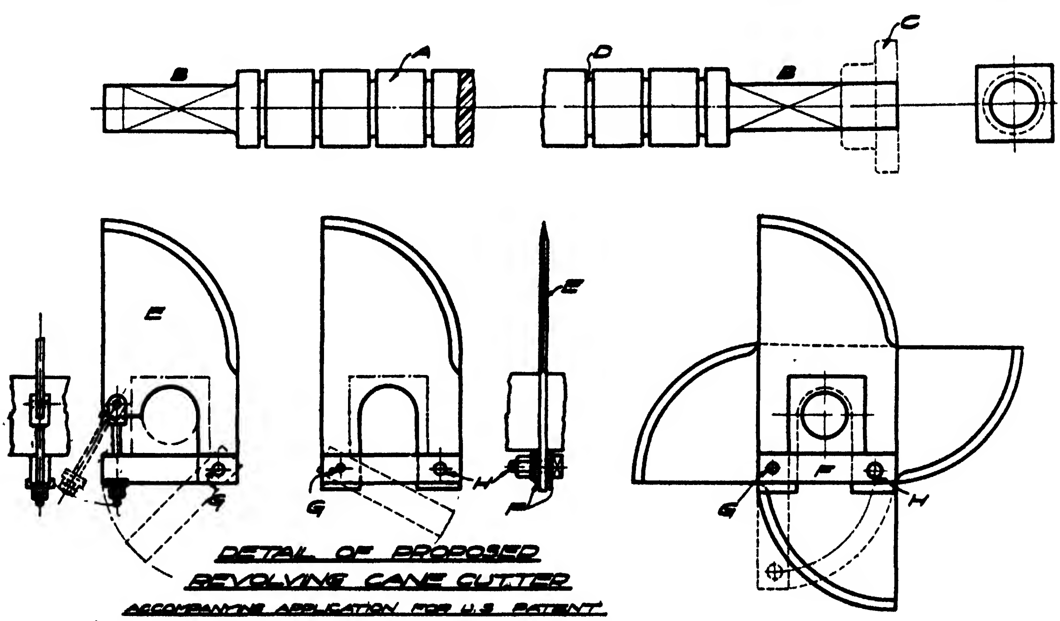


Fig. 1. Improved method of attaching knives in revolving cane cutters.

"In the process of extracting juice from sugar cane by crushing in roller mills, it is found advantageous to cut the cane just before it enters the first roller mill. The cutting is done by revolving knives.

"There are a number of different designs of revolving knives which all do more or less satisfactory work as far as the cutting of cane is concerned. All designs are alike liable to damage by pieces of metal (car links, chain, etc.) and stones passing along with the cane. It is desirable to replace any one of the knives without disturbing the adjacent ones or the system as a whole. The following description embodies this desirable feature of detachability of any one knife from the square shaft rotor without affecting any one of the other knives. (See Fig. 1.)

"A square shaft (a) preferably of steel is turned down at the ends (b) to be journaled in proper journal boxes, and one or both ends are extended beyond the journal to receive a pulley or coupling (c) to rotate it.

"At the desired spacing of the knives, grooves (d) are cut by lathe in a shaft of the proper width and depth to engage the butt ends of the knives. The knives (e) are made of flat steel with a tool steel cutting edge, and may be shaped as shown in accompanying sketch. The accurately-machined concave part of the knife snugly fits the cylindrical part of the shaft (a) at the bottom of the grooves (d).

"Of the two methods shown of mounting the knives on the shaft, the one having a swing bolt is preferred.

"The two plates (f) are hinged on a stout machined rivet (g). When placing a knife in the grooves these plates (f) hang in a vertical position, clearing the square of the shaft. After the knife rests at the bottom of the groove the two plates are brought up against the lower flat part of the square shaft. When using the swing bolt it engages the plates tightly against the bottom flat of the shaft, then the nut is set up pressing against the channel-like washer. The channel keeps the plates positively in position.

"In the other method, instead of the swing bolt a bolt (h) is used which passes through the plates (f) and the extended part of the knife as shown.

"It can readily be seen that to replace any one knife in a set only one swing bolt or a plain bolt needs to be manipulated, and the operation requires but a few minutes.

"The importance of this achievement will be appreciated not only from the very valuable point of saving time, but also, in the case of a broken knife, to put the rotor back in balance in a few minutes. In other designs the whole rotating system has to be removed and totally or partly dismantled in order to get at one knife. And the other point of value is that the fastening of the individual knives cannot throw the shaft out of true. This is important, as the shaft revolves at about 500 R.P.M. and any unbalancing or distortion of the shaft causes destruction to the bearings as well as other troubles."

Mr. Geo. Duncan, of Olaa Sugar Co., reports "that he is working on a scheme that he thinks will eliminate the breakage of knives, but at the time of writing it was not completed."

Mr. J. L. Renton, Ewa mill, reports a "great reduction in the amount of knife breakage, as much as 75% to 80%, by increasing the diameter of the hubs two inches, thereby decreasing the knife overhang by one inch. All knives are inclined right or left and sharpened to the center. The width of knife blade was increased from 4½" to 6"."

The writer wishes to say a word here in favor of the ball bearing and its use in connection with the revolving knife.

To give a schedule of the various machines where the ball bearing can be satisfactorily employed in the sugar factory would be difficult, but for the application of the ball bearing to the revolving knife, I feel quite safe in stating that it will be found more than satisfactory. In four years' experience with the ball bearing at the Puunene mills, 1,600,000 tons of cane have been ground without any delay due to these bearings. They are the S. K. F. type and are self-aligning, so that any temporary bending strain that might be thrown on the shaft while cutting through a heavily overloaded carrier is readily taken up within the bearing itself.

The bearing is enclosed in a dust-proof case, and lubricated by a medium oil,

which is circulated by a steam pump through the bearings and oiling system, the latter being a very simple home-made affair. It is true, the initial cost of this form of bearing is greater than that of any other type, but, then, when one figures the saving in grinding time, where any delay runs into money at a tremendous rate, to say nothing of the saving of power, the initial cost should not be such a deciding factor.

Without proper lubrication, and the right quantity of oil between two rubbing surfaces, there will be a friction loss which goes on day by day and which means an increase in fuel bills. This may not be noticed in some of the factories where they have an ample supply of bagasse; but where the bagasse supply is barely sufficient, and where fuel oil is used, any unnecessary friction will increase the cost of production.

Crushers.

The full mill size cast iron crusher is now generally recognized as the most efficient. Owing to its large diameter and full mill length the range of flexibility of grinding speeds at this station is greatly increased. Other advantages are an increase in extraction of 50% to 75% in some cases over the smaller-sized roller, a greater hydraulic pressure maintained, and the feed of a more even thickness entering the first mill rollers or shredders, as the case may be.

Mr. J. W. Kennedy, of Pepeekeo, reports the following on Crushers:

"I have been able to raise the extraction in the past two years, a little each year, due mostly to changing our crusher. We have a crusher about the same as used in the Puunene mills."

Mr. Olsen, of Lihue mill, reports:

"Putting in a 34"x 78" crusher this off-season, replacing a 26"x 72" Krajewski."

Mr. Geo. Crook, Pioneer Mill Co., submits the following:

"We installed the Krajewski type of crusher last year. The crusher is to be speeded up this season, to take care of a higher tonnage through the mill."

Mr. A. J. Horswill, of Makee Sugar Co., reports:

"We have added a cast iron Krajewski crusher, which is doing excellent work."

Puunene mill reports:

"The two sets of full-size cast iron Krajewski crushers installed in the Puunene mills in 1916 are still on the job, and have been doing good work. In the last five years a great deal of iron and steel, principally in the form of car pins and link, have passed through these crushers without any injurious results, owing to the great flexibility of the hydraulics."

Shredders.

The shredders at Puunene mills were equipped last off-season with the

S. K. F. type of thrust bearing, and though they gave some trouble at first, it was not due to any fault of the bearing, but to the fault of the setting, which was too close. A 1/32" end clearance was allowed each bearing and no further trouble was experienced. As an experiment, one set of grate bars was removed during the last grinding season with no apparent change in the quality of the shredding. With the reduction of power, required to drive the shredder, in mind, the removal of as many grate bars as possible without interfering with the quality of the work, suggested itself. This season our shredders will be operated with a cutter bar, and two sets of grate bars only, thereby allowing more space for the shredded cane to escape as well.

Mr. Olsen, of Lihue mill, reports the following:

"I might mention here a few notes on the conveyor between the crusher and shredder (which is the usual chain and flight type) which might be of interest. We found that when the bottom plate of the conveyor was cut off square with the conveyor or parallel with the shredder it allowed the crushed cane to fall into the shredder all at once, causing quite a fluctuation on the load of the motor. At the same time the feed of the mill was very uneven, being heavy in the center and light on the ends.

"After experimenting with a Λ-shaped feed plate at the head end, we finally got a feed plate that allowed the cane to drop first at the ends and continued discharging until the center was reached, and we found an even feed on the first mill, allowing us to set the mill closer. At the same time the load on the motor was practically constant and the shredder ran a good deal quieter."

Intermediate Conveyors.

A number of new ideas in intermediate conveyors have been in successful operation the past two years. At Puunene soon after the shredders were per-

Fig. 2. Side view of carrier in use at Puunene mills.

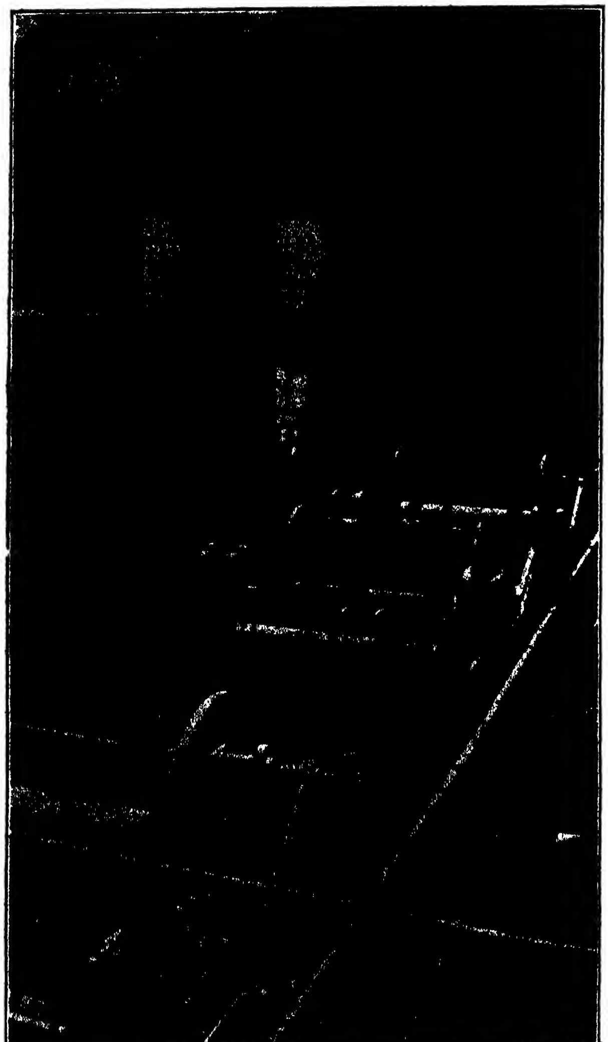


Fig. 3. View looking down on carrier arrangement at Puunene.

manently installed it became apparent that, eventually, we would have to provide some better type of conveyor between the mills, for the wide canvas belts then in use had served their usefulness. Owing to the nature of the material conveyed being changed, from the chip form to the very finely-divided shredded state, it was impossible to keep it from working out between the belt and side plates. In the off-season of 1918, the Ramsay type of drag conveyor was installed between the third and fourth mills, in "B" train, as a trial. The conveyor worked well until it became necessary to speed up to a greater tonnage. At 50 tons an hour, the cane would collect between the head shaft and angle iron slats; so that the chain would be slipped off the sprockets or broken. The experience had its benefits as well, however, and the following year two conveyors were installed between the first, second, and third mills, with the head shafts elevated to such a height that it is now impossible to choke the conveyor or interfere with its feeding the mill.

The following year this type of conveyor replaced the belt conveyors throughout the mills, and they have worked very satisfactorily.

We have Ramsay scrapers on all the mills and macerate partly through the scrapers, the remainder being applied after the blanket is divided by the conveyor slats. The floor plate of the conveyor is on such a steep angle, any excess maceration flows to the lower end rapidly and is again taken up by the oncoming blanket of cane.

Fig. 4. Side view and clearance of Meinecke intermediate chute.

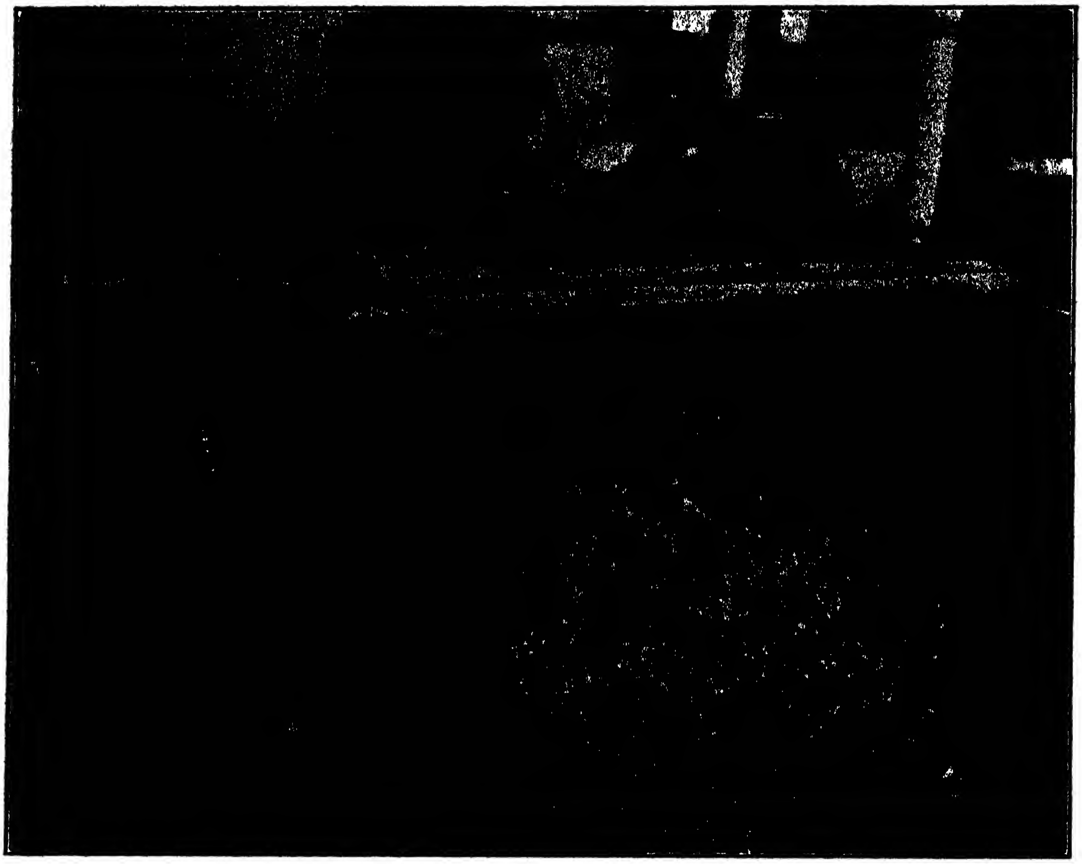


Fig. 5. Meinecke intermediate cane chute, showing cane sliding down chute into succeeding mills.

By the removal of a dozen small bolts, that are readily accessible, the whole conveyor can be removed in as many minutes.

Another advantage is a great deal of space under the conveyors, thereby admitting ample light and making it possible to walk all around any of the mills at any time, whether the mills are grinding or not.

Inspections can then be made at any time, and possibly serious breakdowns prevented, provided the warning be heeded and action taken in time.

Every drop of maceration applied must be taken up by the cane blanket passing along this conveyor, for there is no other possible avenue of escape. The same can be said of the shredded cane, thereby relieving some of the strain that would otherwise fall on the juice screens and cush-cush conveyor. The head end of the conveyor being high above the feed roller, the cane, on sliding down the chute into the mill, is subjected to a turnover, or rolling motion, on the way down, so that the over-saturated cane will be thoroughly mixed with the dry.

Figs. 2 and 3 show the conveyors in use at the Puunene mills.

The Meinecke Intermediate Chute.

During the grinding of the 1920 crop at Paia mill, a very interesting and successful experiment was carried on by Mr. J. Meinecke with an intermediate chute between the second, third, and fourth mills.

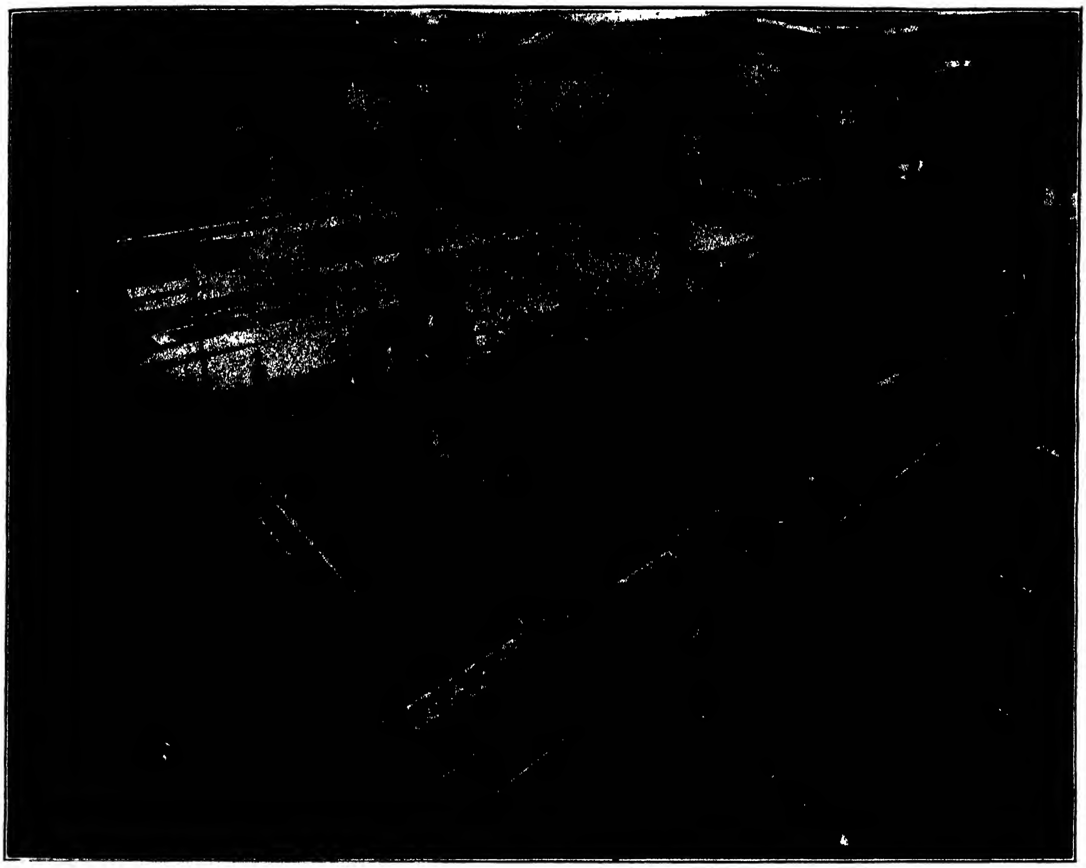


Fig. 6. Meinecke intermediate cane chute, showing top hinged cover opening for cleaning.

These chutes have replaced the old form of Link Belt and chain conveyor, with its many moving parts and its most unsanitary feature, that of the collection of fine particles of chopped cane between the slats; to say nothing of the delays due to this form of conveyor constantly breaking down.

The Link Belt and chain type of intermediate conveyor will soon be a thing of the past in Hawaiian mills, for it is being rapidly replaced with far more reliable types.

The Meinecke chute when properly built and installed should be free of breakdowns, as there are no moving parts to break. They are built of heavy steel plate throughout, and securely bolted to heavy angle iron flanged side plates, and at the same time, should any mill breakdown require the removal of the chute, it can be very quickly accomplished by the removal of a few bolts on each end, and lifting the chute up out of the way as one piece.

Referring to Fig. 4, one will get a general idea of the designs and arrangement of this chute. The crushed cane as it is discharged from the mill enters the space bounded by the bottom, sides, and top plates, and is pushed up the incline to a point almost directly above the man's head, and then drops by gravity into the feed of the succeeding mill.

The cane does not pack tightly on its way up the chute; in fact, before reaching the highest point of the chute the thick blanket of cane is clear of the top plate, from 4″ to 6″.

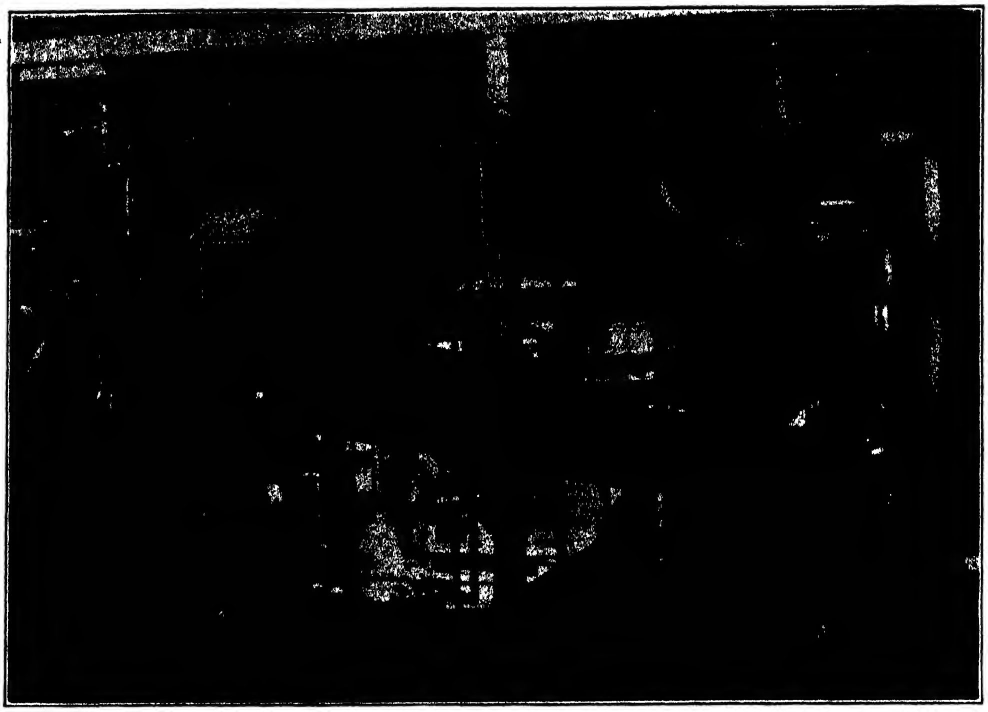


Fig. 7. Meinecke intermediate cane chute, side view, 21′-6″, centers of mills. To anyone not familiar with the mill, it might be well to explain that the cane enters this chute on the right-hand side.

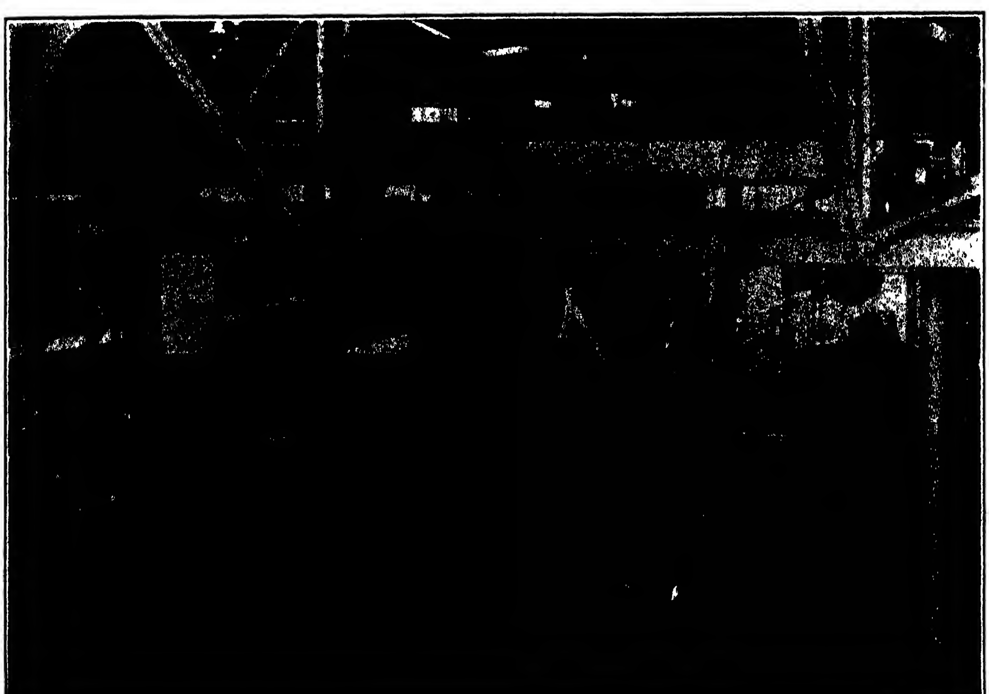


Fig. 8. Meinecke intermediate cane chute, showing cover plates in place.

The maceration is added at the highest point, as the blanket turns to descend into the next mill. Fig. 5 shows the cane sliding down the chute into the next mill.

The top or cover plate of the chute is made to hinge on one end. By the removal of three bolts on each side of the cover, it can be quickly lifted up and out of the way, thus making it quite an easy matter to remove the remaining cane that will be left in each chute after the mill shuts down for the week end.

Fig. 6 very plainly shows the cover plates fastened up and out of the way.

Mr. Meinecke has installed his cane chute between all of his mills at Paia for the 1921 crop, and in one case, between the sixth and seventh mills, the chute is fitted to a Ramsay macerating scraper, part of the maceration to be added as the cane passes through the scraper and the balance as it turns to slide down the chute into the mill. Fig. 7 is a side view of the chute between the first and second mills, and your attention is called to the much greater distance between mill centers in this installation. These mills are 21′ 6″ centers.

To any one not familiar with this mill, it might be well to explain that the cane enters this chute on the right-hand side.

Mr. Meinecke feels that this long chute can still be classed in the experimental stage, owing to the much greater distance that the cane must travel, and to the fact that this chute has not been tried out yet.

This experiment will be watched with much interest, and until its success has been assured the old conveyor directly below the chute will be left in place.

Fig. 9. Some of the discarded parts.

Juice Strainers.

In some mills the juice strainer is a constant source of trouble, and is responsible for considerable loss of time, due principally to poor design, such as insufficient capacity in screening area and in cush-cush conveyors.

The completely closed in strainer or the "fixed-for-the-season" type, is about

the poorest arrangement that could be placed in any modern mill of today, where they care anything at all about high extraction.

The chances for ferment, with its resulting loss of sugar, under the screens, and around the closed-in unwashable juice compartments of such an arrangement are very great in a season's run.

Juice screens should be made portable so that they can be removed at week-end stops, scrubbed on all sides with good stiff brushes, and washed off with a good strong force of water. One cannot be too vigilant in the care and attention around the juice strainers.

If there are any compartment tanks in use at all, they should be of generous proportions to allow for the fluctuations in juice levels which might be caused by an excessive amount of cush-cush at times taking up large quantities of juice, to insure a constant supply of return juice for maceration purposes, and to prevent flooding, with the consequent mixing of the juices.

It is of paramount importance that the tanks be supplied with some form of sight glass on one side so that the attendant can see the juice level at any time, and regulate the supply to the preceding mill accordingly.

Without some sort of an arrangement like the above, one would be working in the dark and be compelled to guess at the juice levels.

These sight glasses, being in plain view, tend to keep the man on the job as well.

The Peck Revolving Juice Strainer.

Something decidedly new and original in juice strainers has been designed by Mr. S. S. Peck.

This strainer is of the revolving type and is arranged to be placed on the top of each mill.

Referring to insert, a description of the construction and operation can be more closely followed.

The strainer consists of two cast iron heads connected by angle iron frames which carry two wrought iron hoops on which the screen joints are made. The screens are put on in three sections and fastened up by clamped rings. These rings carry the paddle frames, which are also in three sections. In replacing a section of screen only the rings and paddles belonging to that section have to be disturbed. If two paddles in the width of a section are desired, extra paddles may be put on the rings.

The wire cloth is reinforced by a heavy screen of very coarse mesh, and the whole drum or strainer, which can be driven by a sprocket and chain from the top roller, revolves partly enclosed in a steel casing, the latter serving as a container for the juice and cush-cush. The juice and cush-cush are pumped together and piped to flow over the upper right-hand side of the screen, which is revolving in the same direction as the top roller.

Some of the juice will pass through the screen at the top, the remainder

ıaking up through the bottom, where it is all quickly removed by means of the threc suction pipes leading to a pump.

The cush-cush is pushed along by means of the screened paddles and is dropped into the mill.

Six small steam nozzles are arranged to spray the screen from the inside, removing any cush-cush that might otherwise be carried around.

There are no installations of this screen, but should it prove a success after trial, it will have a number of advantages over all others.

This screen is what one might call one of the sanitary type. It can be efficiently washed off a number of times a day and kept as clean as a whistle without much effort.

There are no slats dragging across the screening surface to plug up the perforations with cush-cush and eventually force it through into the juice.

The Fifteen-Roller Mill.

With a few notes and figures at hand relative to experiences with the fifteen-roller mill at Puunene, the writer feels that a brief review of the results, and a description of the arrangement, will be of interest to the members of this Association.

Due to the long continuous drought conditions through which our 1919 crop had to pass, returns fell far below the average for this plantation.

Harvesting the crop was slow compared with other years, our rate of grinding falling off to 96 tons an hour, so that the shutdowns for cane amounted to considerable of the total time.

It is usually the custom here to start the grinding season early, and with one mill only, until conditions become more favorable for harvesting. When the cane ripens faster, and over larger areas, the second mill is then put in operation. About the same tapering off at the end of the grinding season takes place, due to the planting requiring gangs of men that have to be supplied from the harvesting fields.

Taking these conditions into consideration, it is clearly seen that considerable quantities of extra fuel would be required to tide over these "undercapacity" times, as they might well be called. The boiling-house must be supplied with steam regardless of any other irregularities, and on nearing the end of the harvest the demands for steam from this end of the factory are doubled, due to the low grades that have to be worked off.

With the idea of eliminating these costly delays, the fifteen-roller mill was developed and operated during the past season, the idea being to grind as a fifteen-roller mill up to 85 tons an hour, thereby operating as a single unit over a longer period of time, with a saving of labor and fuel, the quality of the work to remain the same as when operating as a twelve-roller mill, grinding at 50 to 60 tons an hour.

To make it clear to all, I might mention here that the Puunene mills, consisting of two twelve-roller units, are arranged in parallel and are known as the "A" mill and "B" mill.

The "A" mill hydraulic accumulators, "B" mill engines and gearing occupy the space between the two sets of mills, they being about 60′ apart.

A steel conveyor 5′ wide and 60′ long was built and installed to fit in under the bagasse elevator of "A" mill on one end, and above the bagasse elevator of the "B" mill on the other end.

The cane, after leaving the fourth mill in "A" train, is conveyed to the fourth mill in "B" train, which we now call the fifth mill. This conveyor is driven by an electric motor controlled by the fifth mill engine-man with a switch near his engine. A shutter-like door is built into the "A" mill bagasse elevator, so that the cane can be diverted, either to the fire-room when operating as a twelve-roller, or to the fifth mill when operating as a fifteen. This change can be made in five minutes' time.

The cane after passing through the fifth mill is elevated into the fire-room in the usual manner.

Hot water maceration is added to the cane as it leaves the fourth mill, all the fifth mill juice being returned before the fourth mill by a centrifugal pump through a Ramsay scraper.

Approximately 26.25% of our crop was ground with the fifteen-roller mill, and some remarkable figures were obtained in tons of cane ground per hour, as well as extraction. The saving in fuel oil was difficult to determine, owing to a considerable outside fluctuating load that had to be taken care of by the turbo generators, though the saving was considerably over the oil consumption of the previous year, up to the time that it became necessary to operate as two twelve-roller mills.

The rate of grinding was increased from day to day until the record of 101.02 tons of cane an hour was established. This rate was maintained for one day only, though the two previous weeks were record runs of 92 and 93 tons per hour respectively.

The shredder walked away with the load, and the quality of the work was excellent. Apparently this load could have been increased 100% as far as the shredder was concerned.

No difficulties were experienced with the main engine, which is a 28″x 60″ Nordberg Corliss, with the long range valve gear, driving the first nine rollers at 57 R.P.M.. The fourth and fifth mill engines operated at 55 R.P.M.

The mill settings were not specially set to grind at this rate. The same setting was used for both rollers and returner bars, while grinding as twelve-roller mills at 60 tons per hour.

The following table is made up from the monthly reports, and is a clear record of the performance of this fifteen-roller mill that can be followed from month to month.

The final crop figures for the fifteen-roller mill are included at the bottom of this table:

	Nov. and Dec.	Jan.	Feb.	March	April	May	June
Hours grinding	556.00	349.00	109.75	13.00	140.75	71.25	40.00
Tons cane per hour....	79.74	89.92	67.47	71.55	63.05	57.29	55.29
Cane: Tons	44,335.950	31,380.385	7,405.065	930.100	8,874.515	4,082.020	2,211.750
Tons sucrose ...	6,462.89	4,718.68	1,145.98	155.48	1,463.66	689.77	362.75
% sucrose	14.58	15.04	15.48	16.72	16.49	16.90	16.40
% fiber	11.14	10.67	10.75	10.22	9.57	9.39	10.94
Bagasse: Tons	8,868.16	6,211.63	1,383.23	166.30	1,452.82	662.72	418.72
Tons sucrose..	68.29	60.00	8.87	1.06	8.32	4.05	1.78
% sucrose....	0.77	0.97	0.64	0.64	0.57	0.61	0.43
% moisture..	43.03	44.49	41.21	41.53	40.44	40.83	41.41
% fiber	55.70	53.92	57.53	57.18	58.47	57.83	57.77
Dilution % normal juice.	25.15	26.04	42.15	36.26	45.44	49.51	48.60
Extraction	98.94	98.73	99.23	99.32	99.43	99.31	99.51

FINAL CROP FIGURES FOR 15-ROLLER MILL.

Hours grinding	1,279.75
Tons cane per hour..............................	77.53
Cane: Tons	99,219.785
Tons sucrose	14,999.21
% sucrose	15.12
% fiber	10.74
Bagasse: Tons	19,163.58
Tons sucrose	152.37
% sucrose	0.80
% moisture	43.05
% fiber	55.60
Dilution % normal juice	30.14
Extraction	98.98

Total tons of cane ground by 15-roller mill.......	99,219.785
Highest grinding rate	101.02 tons per hour
Highest extraction over a period of 15.5 hours....	99.57
Fuel oil saved measured in dollars and cents......	$6,560.00

In the writer's opinion, the 15-roller mill equipped with a Searby shredder is about the finest arrangement of milling machinery that could be placed on a foundation bed.

The possible range of flexibility is enormous with such equipment, as well as being most efficient.

In conclusion I wish to thank the following gentlemen for data furnished of their respective mills, and Mr. A. F. Ewart for his contribution on knives: J. L. Renton, Geo. Crook, O. Olsen, Geo. Duncan, A. J. Horswill, J. W. Kennedy.

Report of the Committee on Indicating and Recording Instruments.*

By J. H. Pratt.

As this is an entirely new subject to be discussed by the Hawaiian Chemists' Association, I will endeavor to give a general view of the various types of apparatus that are obtainable and of the uses to which they may be put, rather than to attempt to tabulate a summary of present installations. The chief value of these instruments is that they not only show what is being done at any particular time, but also show what has happened when one's back is turned. The worth of these instruments is entirely dependent upon the use that is made of the information that they give.

The uses to which indicating and recording instruments may be put in a sugar factory are almost innumerable. The rapid rise in the cost of fuel during the past couple of years is rendering their services more important yearly. Fortunately, the amount of fuel needed in addition to the bagasse is, in most factories, small, but the demands on the fireroom for additional steam are increasing from year to year. Higher extraction, greater recovery, and larger-grained sugar are but synonyms for more steam. Each year the boilers are required to furnish power to drive additional machinery, to evaporate a higher dilution, to make a few more "cuts," or to run a distillery, paper plant, mule feed factory, or other profitable by-product.

For these reasons, the place where most mills start installing these instruments is in the fireroom, and it is possible to get an instrument for every need. Probably the most important of these is the CO_2 recorder, the importance of which is shown by the following table (U. S. Bureau of Mines):

Per Cent CO_2 ...	16	15	14	13	12	11	10	9	8	7	6	5	4	3
% Loss in Fuel..	10	12	13	14	15	16	18	20	23	26	30	35	45	60

There are many makes of CO_2 recorders, practically all being based upon the absorption of CO_2 by caustic potash (either as a solution or in cartridges) and the measurement of the per cent of gas removed. Some of these operate continuously and others intermittently with the intervals able to be regulated. Their principal difficulty is in collecting the sample of gas, due to the ashes, soot, etc., plugging up the pipes, gas washers, and filters. One company makes an automatic gas collector, so that should a CO_2 instrument prove too expensive an installation for a very small mill, samples may be collected automatically for any length of time from one to twenty-four hours (rate of collection can be altered easily) and analyzed with an ordinary Orsat apparatus. Another firm of makers tackles the problem from a different angle—they regard the air as the fuel. A steam flow meter records the steam production on the chart (in red ink), and an air meter records the flow of air (in blue). With perfect com-

*Presented at Eighteenth Annual Meeting of the Hawaiian Chemists' Association, held jointly with the Hawaiian Engineering Association, November, 1920.

bustion, the two curves follow the same line; when the red curve is highest there is a deficiency of air, etc. Specimen charts on which the CO_2 curve had been plotted by hand, show that the latter follows the other two curves extremely closely. An Orsat or other CO_2 apparatus may be used as a cheap substitute for a steam or water-flow meter. CO_2 is introduced into the flow of steam at a known rate, and after time for thorough mixing, a sample is drawn off and the per cent CO_2 determined, thus giving the amount of steam. This method is accurate to within 1½% to 1% when using only one pound of gas to a ton of steam. This method of Mr. E. G. Bailey is very easily installed, requiring only the drilling and tapping of two small (⅛") holes in the steam line.

Draught gauges are made in several different types. The most common seems to be the liquid angle gauge. One make of these is very easily calibrated, as the scale is readily movable and may be set at the correct zero in the minimum time. A second type is the differential or U tube. Other kinds of draught gauges use German silver diaphrams or Bourdon tubes. Some makes of instruments indicate the draught in as many as five places in the passage of the gases with one instrument.

Steam and water meters are all based upon the "flow" principle and may be divided into two classes. The impact principle is used in the "pitot" tube, the "vortex", and the "metering bend"; the change in velocity type covers the "venturi" tube and the "orifice." The latter seems to be by far the most common type with the makers. The value of these instruments in measuring the boiler feed water, steam produced, and the steam used at various parts of the factory, such as the power-house, evaporators, pans, etc., is very obvious.

Probably the most common recording instruments in a sugar factory are pressure and vacuum gauges. The actuating mechanism is usually a single or double Bourdon tube, a helical tube, or a Sylphon metal diaphram. In some instruments the movement at high pressures is modified by an enclosing spring so that the vacuum scale is magnified; i. e., in a gauge registering vacuum and up to 250 pounds pressure, the vacuum would take up only 1/18 of the chart, while with a suppressed movement it would occupy ¼ of the chart. The places where these instruments could be installed would make a long list. The most prominent are: the steam and juice sides of the evaporators, pans, and juice heaters, on steam lines, engines, and pumps, water lines, fire line, etc.

Thermometers are in three general classes—those depending upon the expansion of an inert gas or air, the vapor of a volatile liquid, or of a liquid itself. The claims of the makers of these various types are very overlapping, but the favorites are nitrogen, alcohol, and mercury. In some, the movement of the helical or spiral tubes gives sufficient motion to the pen arm; in others it is multiplied by the use of rack and pinion, or links, levers, etc. By using a large bulb, the capillary tube connecting the bulb with the recording chart may be several thousand feet long, and by use of electrical apparatus, it may be even miles long. In many makes the action of heat on the capillary tube is compensated for by several ingenious devices. Some thermometers are equipped with electrical attachments which turn on a lamp or ring a bell when the temperature rises or falls to any desired limits. For condensers a special apparatus is made showing the temperature of the water entering and leaving, and the vacuum, all

on the one chart. Recorders are made with several pens on the same chart, and on some makes the arms can cross each other. One type of thermometer uses a nitrogen-filled tube, acting upon a simple U tube filled with mercury, one end being open to the atmosphere. The pen arm is attached to a float in the mercury.

Closely allied to thermometers are thermostats. There are several types of these. The electric ones are operated by the expansion of a medium (bi-metal bar) contained in the thermostat element or, for higher temperatures, by either a base-metal or platinum couple, similar to those used in pyrometers. Those using compressed air operate on a rubber diaphram or an all-metal bellows of the Sylphon type. Like the thermometers, these also may be equipped with an alarm light or bell. I believe that several factories in these Islands have been using this apparatus on their juice heaters for several years with much success.

Pyrometers measure the very small current generated by heating a pair of joined wires of different alloy. These thermo-couples are usually platinum and platinum-rhodium for high temperatures, and "base-metals" (such as nickel and chromium) for lower temperatures. The best instruments are compensating; i. e., variations in temperature of all but the fire end of the tube are corrected for. By the use of special switches the curves for different fire-ends may be plotted on the same chart. One firm of makers have over ten thousand of their instruments in use, and eight sugar refineries are on their list.

Time and motion recorders can be obtained with as many as twenty pens on the same chart. They can be operated by alternating or direct current or by dry-cell batteries. In most places in the sugar house their place could, I think, be well taken by other instruments, such as vacuum, pressure, or temperature gauges. They might, however, be very useful in keeping the time of grinding and the delays, and give also a good check on the centrifugal men, particularly when experimenting with different methods to hasten drying of low-grade. One testimonial states that they prove much more satisfactory for conducting experimental runs than a stop-watch, as the latter has a bad effect on the operatives. I believe that Waialua is using one of these time recorders to keep track of the delays at the milling plant. It has twelve pens, one for the total time shut down and the others for the main causes for stopping.

Liquid level gauges are used in several factories to keep a check on the filling and weighing of the mixed juice. Recording Brix instruments were tried out at Puunene several years ago, but did not prove satisfactory.

There are many and varied types of Tachometers, but their use in a sugar factory is rather limited. Some operate like an ordinary ball governor, others lift a column of mercury, others run a small electric generator, while others vibrate a series of tuning forks.

Automatic counters come in a variety of forms and prove very useful in counting the number of bags of sugar made, the revolutions made by engines, tanks of juice filled or weighed, etc.

As I previously stated, the value of these instruments is almost entirely dependent upon the use that is made of the information given by them. Unfortunately, very few of these instruments are equipped with any integrating devices,

so that planimeters are necessary. These are made by most of the instrument manufacturers and are comparatively inexpensive.

For the convenience of those contemplating the purchase of recording instruments, I append the following partial list of manufacturers. I am also turning over to the secretary of this Association catalogues of nine of these companies:

The Bristol Company, Waterbury, Conn.
The Brown Instrument Co., Philadelphia, Pa.
The Foxboro Company, Foxboro, Mass.
Schaeffer & Budenberg Mfg. Co., Brooklyn, N. Y.
C. J. Tagliabue Mfg. Co., Brooklyn, N. Y.
Taylor Instrument Co., Rochester, N. Y.
Bailey Meter Co., Cleveland, Ohio.
Precision Instrument Co., Detroit, Mich.
Uehling Instrument Co., New York, N. Y.
Powers Regulator Co., Chicago, Ill.
Johnson Service Co., Milwaukee, Wis.
Hoskins Mfg. Co., Detroit, Mich.
Sarco Company, New York, N. Y.

Report of the Committee on Electrification.*

By J. LEWIS RENTON.

With the steady increase in the application of electricity to the sugar mills in the Hawaiian Islands, the question of electrification is an important one to all mill engineers.

STANDARDIZATION.

In the case of D. C. industrial drive, the following voltages have come into almost universal use:

Generator.	Motor.
125	115
250	230
575	550

The following A. C. voltages have come into such common use that they may be considered standard:

* Presented at the Eighteenth Annual Meeting of the Hawaiian Chemists' Association, held jointly with the Hawaiian Engineering Association, November, 1920.

Generator	Transformer	Motor
120	115	110
240	230	220
480	460	440
600	575	550
2,300	2,300	2,200
6,600	6,600	6,600
11,000	11,000	11,000
13,200	13,200	13,200

The usual preference is to use alternating rather than direct-current power, due to the ease of handling, the simplicity of apparatus and, as a rule, the lesser investment involved.

Practically all American-made alternating-current machines are now designed for 60-cycle operation.

The unquestionable superiority of the 3-phase over the single and 2-phase power circuits needs no argument for its adoption.

Leaving out direct-current apparatus, the selection of alternating-current power involves nothing but the selection of the proper voltage, and the tendency seems to be strongly inclined to 440 volts for mill use in the Hawaiian Islands. The voltage to be generated depends on whether the power is to be generated at the factory or at some distant plant, and what use is to be made of the power; therefore, each case would have to be taken up individually, transformers being used to obtain desired voltage for different conditions.

The fewer different voltages used in the different factories in the Islands, the better will be the service rendered by the supply houses here, as it will enable them to keep up a good stock of a few different machines in preference to a somewhat varied selection of many machines. The obvious advantage to be gained is prompt deliveries when necessary.

Wiring.

Cables in conduit or ducts make a more permanent and neater installation, and for that reason much of the new work now going on is of this nature. Its first cost is its chief drawback; besides, in small installations open wiring is preferred by some of the engineers because it is simple, easy to locate trouble, and easy to repair.

Iron conduit should not be employed on alternating current unless all conductors of the circuit are in the same conduit. The general practice is to use iron conduit up to about 2 inches in diameter. For larger sizes, fiber or tile conduit is much less expensive and is satisfactory.

The use of conduit in hot atmosphere, over 100° F., such as is encountered in parts of fire-room and boiling-house, is not recommended by some authorities, as there is apt to be "sweating" in the conduit, causing a breaking down of the insulation with resulting short circuits.

It goes without saying that all wiring and apparatus should conform with the regulations of the National Board of Fire Underwriters.

Electrification of Milling Plant (Rollers).

To compete with the steam engine as a prime mover for sugar-mill roller trains an electrical motor must be dependable, simple, and have a variable speed. Considerable success has been had with the slip-ring or wound-rotor induction motor, which has the good characteristics of the induction motor plus a good starting torque. Variations in speed are obtained by varying the external resistance, in series with the rotor winding, and the usual practice has been to use large grid type resistance.

One of the large electrical manufacturers has put out a "Liquid Type Controller" in place of the grid resistance for the rotor circuit.

The apparatus consists of a tank with an upper and lower compartment, with the electrodes of the rotor circuit suitably insulated and rigidly suspended in the upper compartment. The lower compartment of the tank is for cooling and storage of the electrolyte, which is a suitable mixture of sodium carbonate and water.

The speed of the motor is governed by the height of the electrolyte in the upper compartment, as the speed varies inversely with the resistance in the rotor circuit. A multiple shutter type of weir closes, or opens, the connection between the upper and lower compartments, the maximum resistance being obtained when all shutters are opened. A small motor-driven centrifugal pump circulates the electrolyte from the lower to the upper compartment, thus closing the shutters, and causing the height of liquid in the upper compartment to rise. The shutters are operated by a motor with provisions made for operating them manually if necessary. Horizontal plates fastened to top of electrodes practically short-circuit rotor windings when horizontal plates are covered. An interlocking switch prevents starting motor unless all resistance is in rotor circuit.

The advantages claimed are:

Simple and durable.
Uniform elimination of resistance; therefore uniform speed change.
Any desirable speed; not step by step change of speed.
No contacts broken; therefore no arcing.
No danger of burning out resistance on prolonged operation at slow speed with high resistance in rotor circuit.

Useful Information.

Power Transmitted in Three-Phase Three-Wire Circuits.

P — Power in KW.
1 — Current per wire in amperes.
E — Potential between wires in volts.
Cos ϕ — Power factor.

$$P = \frac{3\ E\ 1\ \text{Cos}\ \phi}{1000}$$

Testing Single-Phase Watthour Meters.

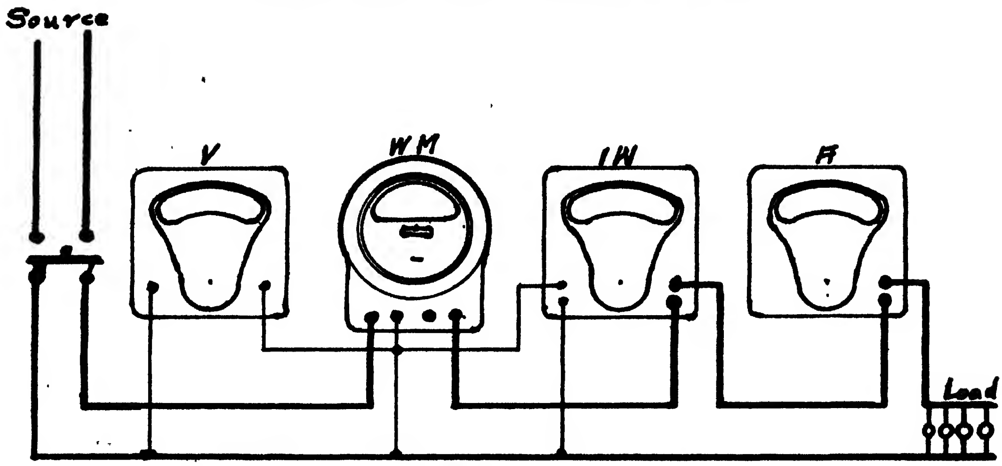


Fig. 1.

Fig. 1 shows a watthour meter connected for test with indicating instruments. The voltmeter and ammeter are not necessary unless it is desired to check the line voltage or to note the power-factor of the load.

The watts recorded by the meter, i. e., the rate at which the meter is recording, can be found by the formula

$$\frac{3600 \times K \times R}{S} = \text{watts.}$$

R — Number of revolutions.
S — Number of seconds required to make this number of revolutions.
K — Constant marked on the meter disk.
3600 — Number of seconds in an hour.

Take a sufficient number of revolutions so that the time of observation will be from 30 to 60 seconds. If materially less than 30 seconds, errors in the measurement of time are probable, and observations of a duration greater than 60 seconds are generally unnecessary.

A convenient method of testing a three-wire meter is to connect the current coils in series and test as a two-wire meter, using the constant marked on the disk.

To check the equality of the two current coils, the meter may be read with load first on one current coil alone, and then upon the other alone, using in this case a calibrating constant equal to the disk constant multiplied by two.

Example: Meter to be tested, 5-ampere, 110-volt, 60-cycle, where K, the constant marked on the disk, is .3.

Suppose the load shown by the indicating wattmeter is 540 watts and that the disk has been found to make 20 revolutions in 40 seconds.

Using the formula it is found that

$$\text{Meter watts} = \frac{3600 \times .3 \times 20}{40} = 540$$

Therefore, the meter is correct. If the disk had made 20 revolutions in 40.8 seconds, the meter watts would be found to be 529.4 and the accuracy:

$$\frac{529.4}{540} = 0.98$$

That is, the percentage accuracy is 98, or the meter is 2% slow.

Method of Testing with Test Meter.

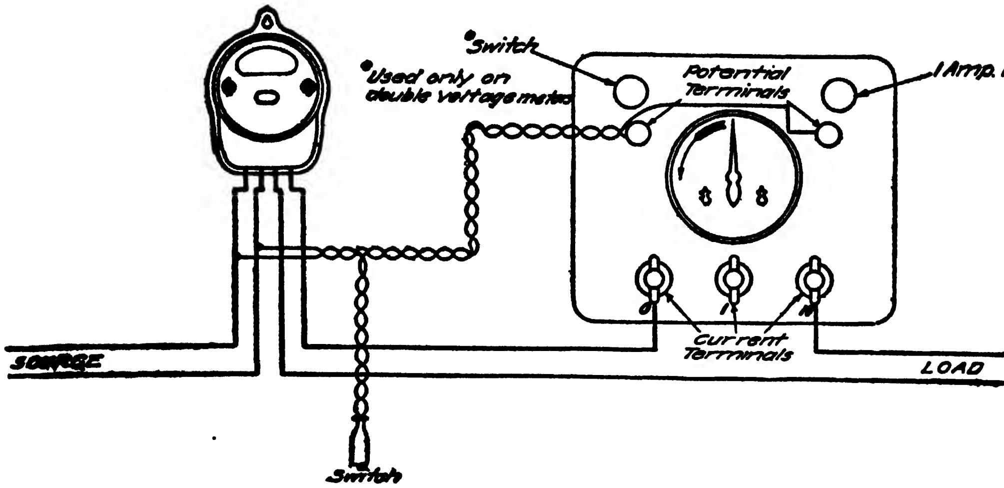


Fig. 2.

The portable test meter provides a means for testing quickly, yet accurately, and independently of load variations. Fig. 2 shows the method of connecting a two-wire watthour meter when testing with a single-phase portable test meter.

Set the meter in a level position free from vibration. Connect the proper current terminals of the test meter, between the load and the meter undergoing test, with connections as shown on the instruction card accompanying the test meter.

Connect the potential circuit to the service switch by means of leads provided for that purpose. Connect the potential circuit of the test meter ahead of the meter under test and the current circuit of the test meter after the meter under test so that neither shall record the losses in the potential circuit of the other and thereby introduce appreciable error at light load. Potential leads with pendant snap switch are provided with each test meter. When properly connected, the large pointer will rotate counter-clockwise. To change the direction of rotation, reverse either the current or the potential leads. The test meter is started and stopped by closing and opening the snap switch.

Stop the test meter register by opening the pendant snap switch and note the reading of the pointers. Start the test meter simultaneously with the counting of the disk revolutions of the meter under test and stop it by the snap switch after the required number of revolutions has been taken and the position of the pointers again noted.

The number of revolutions noted during the test on the dial of the test meter multiplied by the proper constant (depending on the current winding used) gives the watthours recorded by the test meter. The number of revolutions of the disk of the meter being tested, multiplied by its constant (marked on the disk), equals the watthours recorded by the meter under test. Any overrunning of the test meter after the switch has been opened is due to the momentum of the moving element and in no way affects the accuracy of the reading. The over-running at the end of the test is compensated for by the slight lag in starting.

The ratio of the watthours recorded by the meter under test to the watthours recorded by the test meter equals the accuracy of the meter. Take a sufficient number of revolutions to make negligible any errors of observation in reading the pointer indications and to minimize any error due to not starting or stopping the test meter simultaneously with the counting of the disk revolutions of the service meter.

$$\text{Accuracy} = \frac{r \times k}{R \times K} = \frac{\text{watthours of meter under test}}{\text{watthours of test meter}}$$

r — Revolutions of meter under test.
k — Disk constant of meter under test.
R — Revolutions of large pointer of test meter.
K — Constant of test meter.

Example, Case 1. Meter to be tested, 10-ampere, 110-volt, 60-cycle induction meter, when k, the constant marked on the disk, is .6. Assuming that we are testing at approximately full load, we will use the 10-ampere current winding on the test meter which has a constant K equal to .6 as noted on the instruction card in the test meter cover. Suppose the test meter made 25 revolutions while the meter under test made 25, the equation

$$\frac{r \times k}{R \times K} = \text{accuracy}$$

becomes $\frac{25 \times .6}{25 \times .6} = 1.00$ or 100 per cent accuracy, which indicates that the meter is correct.

Suppose, however, that the test meter registers 24 revolutions while the meter under test made 25, the equation would be $\frac{25 \times .6}{24 \times .6} = 1.041$, indicating that the meter under test is 4.0 per cent fast.

Again suppose the test meter registered 26 revolutions while the meter under test made 25, the equation would be $\frac{25 \times .6}{26 \times .6} = 0.962$, indicating that the meter under test is 3.8 per cent slow.

When testing a meter operating from instrument transformers the constant of such a meter must be divided by the product of the ratios of the transformers.

NORMAL RATED AMPERES, THREE-PHASE INDUCTION MOTORS.

H. P.	Speed	110 v.	220 v.	440 v.	550 v.	2200 v.
1	1800	7.0	3.5	1.7	1.4	
1	1200	6.9	3.4	1.7	1.4	
1	900	8.1	4.0	2.0	1.6	
2	1800	11.3	5.7	2.8	2.3	
2	1200	11.8	5.9	2.9	2.4	
2	900	12.3	6.1	3.1	2.5	
3	1800	15.9	7.9	4.0	3.2	
3	1200	17.2	8.6	4.3	3.4	
3	900	18.2	9.1	4.5	3.6	
5	1800	25.5	12.7	6.4	5.1	
5	1200	27.0	13.5	6.8	5.4	
5	900	28.7	14.3	7.2	5.7	
7½	1800	37.0	18.5	9.2	7.4	
7½	1200	38.7	19.3	9.7	7.7	
7½	900	41.6	20.8	10.4	8.3	
10	1800	48.8	24.4	12.2	9.8	
10	1200	50.4	25.2	12.6	10.1	
10	900	56.2	28.1	14.0	11.2	
15	1800	75.0	37.5	18.7	15.0	3.7
15	1200	75.6	37.8	18.9	15.1	4.0
15	900	81.0	40.0	20.0	16.2	
20	1200	101	50.0	25.0	20.2	5.2
20	900	104	52.0	26.1	20.9	5.8
20	720	120	60.0	30.0	24.0	5.8
25	1200	....	62.4	31.2	25.0	6.1
25	900	....	66.5	33.2	26.6	7.5
25	720	....	66.0	33.0	26.4	7.2
35	1200	....	84.5	42.3	33.8	8.9
35	900	....	89.4	47.7	35.8	9.1
35	720	....	92.5	46.2	37.0	9.8
50	900	....	123	62.0	49.4	12.8
50	720	....	128	64.0	51.0	13.7
50	514	....	138	69.0	55.0	14.2
75	900	....	184	92.0	74.0	19.0
75	720	....	190	95.0	76.0	19.3
75	514	....	206	103	82.0	20.6
100	720	....	246	123	98.0	23.2
100	600	....	260	130	104	25.5
100	450	....	270	135	108	27.0
150	720	....	....	181	145	31.8
150	600	....	....	185	148	37.4
150	450	....	....	200	161	45.0
200	600	....	....	241	193	50
200	514	....	....	252	202	53
200	400	....	....	268	214	53

STANDARD INSULATED CABLES FOR INSTALLATION WORK.

Ampere Range		Amps. Normal Rated Load	No. Cables	Size	Temp. Rise, ° C.	
From	To				Full Load	50% Overload
1	9	8	1	No. 12 B & S Solid	10	20
10	14	12	1	No. 10 " "	14	28
15	24	20	1	No. 8 " "	10	20
25	36	30	1	No. 6 " "	9	18
37	56	45	1	No. 4 " Stranded	10	20
57	84	70	1	No. 2 " "	10	20
85	124	100	1	No. 0 " "	10	20
125	169	150	1	No. 000 " "	12	24
170	184	175	1	No. 0000 " "	12	24
185	224	200	1	250,000 C M	12	24
225	264	250	1	300,000 "	14	28
265	324	300	1	400,000 "	13	26
325	374	350	1	500,000 "	12	24
375	499	450	1	750,000 "	12	24
500	649	600	1	1,000,000 "	13	26
650	749	700	1	1,250,000 "	12	24
750	899	800	1	1,500,000 "	13	26
900	1099	1000	1	2,000,000 "	12	24
1100	1299	1200	2	1,000,000 "	13	26
1300	1599	1500	2	1,250,000 "	14	28
1600	2249	2000	2	2,000,000 "	12	24
2250	2649	2500	3	1,500,000 "	14	28
2650	3349	3000	3	2,000,000 "	12	24
3350	3599	3500	4	1,500,000 "	15	30
3600	4399	4000	4	2,000,000 "	12	24
4400	5599	5000	5	2,000,000 "	12	24
5600	6600	6000	6	2,000,000 "	12	24

NOTE:—Temperatures in first column are based on continuous operation at normal rated load; second column on 2 hours' operation at 50% overload. For 50% overload continuously, temperature will be about 11° higher than last column. Maximum raise should not exceed 30° C. Paper insulation—increase all temperatures 10%.

CALCULATION OF SAG AND TENSION.

$$S = \frac{(L)^2W}{8T} \qquad T = \frac{(L)^2W}{8S}$$

Where T = Wire tension in pounds.
L = Length of span in feet.
W = Weight of one foot of conductor and insulation.
S = Sag or deflection in feet.

ANNEALED WEATHERPROOF WIRE.

B & S Gauge......	10	8	6	4	2	1	0	00	000	0000
Breaking Stress....	283	440	700	1114	1772	2234	2818	3553	4480	5650

HARD DRAWN BARE WIRE.

B & S Gauge......	10	8	6	4	2	1	0	00	000	0000
Breaking Stress.....	500	778	1237	1967	3127	3943	4973	6271	7907	9971

NOTE:—In calculating sag, working stress should be taken as one-quarter breaking stress given in table.

SIZES OF WIRES AND CABLES FOR THREE-PHASE INDUCTION MOTORS.

H. P.	Volts				
	110	220	440	550	2200
1	10 B. & S.	10 B. & S.	10 B. & S.	10 B. & S.	
2	10 "	10 "	10 "	10 "	
3	8 "	10 "	10 "	10 "	
5	6 "	10 "	10 "	10 "	
7.5	4 "	8 "	10 "	10 "	
10	4 "	6 "	10 "	10 "	
15	2 "	4 "	8 "	8 "	
20	0 "	2 "	6 "	8 "	
25	....	2 "	6 "	6 "	10 B. & S.
35	....	0 "	4 "	6 "	10 "
50	....	000 "	2 "	4 "	8 "
75	....	250,000 C. M.	0 "	2 "	8 "
100	....	300,000 "	000 "	0 "	6 "
150	....	....	250,000 C. M.	000 "	4 "
200	....	....	300,000 "	250,000 C. M.	4 "

The October number of this year of the *Hawaiian Planters' Record* contains a very interesting article on the actual application of electrification.

The Chairman of the Committee on Electrification wishes to thank Mr. E. B. Gibson for his valuable assistance.

Annual Synopsis of Mill Data, 1920.

By W. R. McAllep.

For the first time the Annual Synopsis contains data from all factories in the Association; a total of forty-two. As has been the tendency from year to year, more nearly complete data have been received from a larger number of factories, particularly from the smaller ones. Unfortunately, however, a greater number of factories than usual have been late in finishing their grinding season and have had to report on the portion of the crop ground prior to September 30, so, though returns have been received from all the factories the figures do not represent quite all of the 1920 crop.

In compiling the three large tables the arrangement similar to that of the two previous years has been followed; that is, the factories are listed in the order of the size of their crop, taking as a basis the average of the preceding five years. The first of these tables is a compilation of the results secured by the individual factories, true averages of these results and for comparison averages for the preceding nine seasons.

Six of the factories on the island of Oahu have been affected by a strike of the plantation laborers. The work in these factories has suffered on account of inexperienced labor and overtaxed boiling house capacity due to low purity juices from cane that should have been harvested earlier. These factories grind a sufficient portion of the total crop so that their results materially affect the averages. In order that the work of the factories that were not handicapped by these conditions may be compared with that of last year, a second set of averages for the years 1919 and 1920 has been calculated, with the data from the factories affected by the strike omitted. These averages appear in Table 9. The second of the large tables is a tabulation of knife, mill and returner bar settings, pressures, roller speeds, etc. The third shows the surface and juice grooving used this season.

Varieties of Cane.

Table 1 shows the varieties of cane ground by the different factories. This table has been rearranged. Varieties making up one per cent or more of the total crop are listed in separate columns and these columns arranged in the order of the tonnage ground.

Comparing the principal varieties with last year, D 1135, H 109, the Tip canes and Striped Mexican show a gain. Caledonia and Lahaina show a loss. 88.5% of the total tonnage is made up of the four principal varieties: Yellow Caledonia, Lahaina, D 1135 and H 109. Yellow Caledonia was ground in appreciable amounts at all but four of the factories. D 1135 is the next most widely distributed, all but 12 factories reporting this variety. Over half of the column headed "Other Varieties" consists of the following, each of which made up one per cent or more of the tonnage ground at one of the mills.

TABLE NO. 1.
VARIETIES OF CANE.

	Yellow Caledonia	Lahaina	D 1135	H 109	Striped Tip & Yellow Tip	Striped Mexican	D 117	Other Varieties
H. C. & S. Co.	..	65	19	16	..	..	..	..
Oahu	4	70	11	8	..	..	..	7
Ewa	14	10	..	72	..	..	..	4
Maui Agr.	6	58	22	6	..	4	..	4
Pioneer	1	63	2	..	..	33	..	1
Waialua	9	37	25	10	..	..	3	16
Haw. Sug.	1	49	29	11	..	..	..	10
Olaa	86	..	14	..	..	..	..	..
Honolulu	44	40	4	11	..	..	..	1
Onomea	82	..	..	..	18	..	..	..
Hakalau	100	..	..	..	..	..	..	..
Kekaha	..	85	14	..	..	..	..	1
McBryde	51	..	30	19	..	..	..	..
Hilo	94	..	5	..	..	..	..	1
Wailuku	3	21	15	19	..	32	..	10
Haw. Agr.	56	..	6	..	..	..	..	38 *
Lihue	100	..	..	..	..	..	.	..
Lihue, Han	99	..	1	..	..	..	..	..
Waiakea	100	..	..	..	..	.	..	..
Makee	96	..	..	..	..	..	..	4
Honokaa	55	..	16	1	28	..	..	..
Laupahoehoe	45	..	10	..	31	..	14	..
Pepeekeo	98	..	1	..	1	..	..	..
Kahuku	47	43	8	2	..	..	..	..
Koloa	94	4	2	..	..	..	..	..
Hamakua	31	..	12	..	15	..	40	2
Hawi	46	..	11	2	40	..	..	1
Paauhau	85	..	10	1	3	..	..	1
Honomu	99	..	..	..	..	..	1	..
Hutchinson	42	..	1	..	5	..	..	52 †
Kaeleku	100	..	..	..	..	..	..	..
Kohala	35	..	30	..	35	..	..	..
Kaiwiki	71	..	7	..	12	..	10	..
Waianae	3	60	..	34	..	..	..	3
Kilauea	99	..	1	..	..	..	..	..
Waimanalo	100	..	..	..	..	..	..	..
Niulii	96	..	1	..	3	..	..	..
Halawa	62	..	10	..	28	..	..	..
Union Mill	52	..	2	..	45	..	..	1
Olowalu	..	100	..	..	..	..	..	..
Waimea	..	78	2	20	..	..	..	..
Kipahulu	100	..	..	..	..	..	..	..
True Average 1920	42.7	26.7	10.0	9.1	3.5	2.5	1.0	4.5
" " 1919	46.4	29.1	7.2	6.8	2.9	1.8	1.1	4.7
" " 1918	42.9	37.9	7.5	4.0	2.0	0.6	0.8	4.3

* Rose Bamboo 7%, White and Yellow Bamboo 18%
† Rose Bamboo.

TABLE NO. 2.

COMPOSITION OF CANE BY ISLANDS.

	Hawaii	Maui	Oahu	Kauai	Whole Group
1911					
Polarization.................	12.91	15.45	14.45	13.51	13.99
Percent Fiber................	13.27	11.79	12.92	13.26	12.85
Purity 1st Mill Juice.........	88.15	91.57	88.20	87.46	88.83
1912					
Polarization.................	13.30	16.00	14.38	14.06	14.34
Percent Fiber................	13.53	11.53	12.62	12.59	12.67
Purity 1st Mill Juice.........	88.40	91.13	88.46	88.30	89.04
1913					
Polarization.................	13.22	15.56	14.21	13.70	14.05
Percent Fiber................	13.74	11.73	12.75	12.50	12.85
Purity 1st Mill Juice.........	88.47	91.11	88.20	88.12	89.02
1914					
Polarization.................	12.75	15.16	14.23	13.62	13.78
Percent Fiber................	13.62	11.59	12.44	12.75	12.74
Purity 1st Mill Juice.........	88.22	91.02	88.11	87.51	88.71
1915					
Polarization.................	12.61	15.23	14.29	14.09	13.77
Percent Fiber................	13.00	11.44	12.77	12.46	12.51
Purity 1st Mill Juice.........	87.86	90.48	87.27	86.99	88.24
1916					
Polarization.................	12.54	14.62	13.74	13.26	13.45
Percent Fiber................	13.22	12.22	12.51	12.86	12.74
Purity 1st Mill Juice.........	87.56	89.41	87.15	86.26	87.70
1917					
Polarization.................	13.31	15.43	13.55	13.13	13.76
Percent Fiber................	13.23	11.67	12.25	12.89	12.62
Purity 1st Mill Juice.........	88.11	90.69	86.86	86.70	88.02
1918					
Polarization.................	11.88	14.25	13.50	12.54	12.97
Percent Fiber................	13.35	11.53	12.23	12.84	12.50
Purity 1st Mill Juice.........	87.27	88.62	86.93	85.88	87.18
1919					
Polarization.................	12.74	15.12	14.24	13.52	13.74
Percent Fiber................	13.07	11.74	12.14	12.61	12.49
Purity 1st Mill Juice.........	87.54	88.81	87.00	85.82	87.34
1920					
Polarization.................	12.86	15.29	13.75	13.07	13.64
Percent Fiber................	13.36	11.39	12.65	12.72	12.64
Purity 1st Mill Juice.........	87.87	88.94	85.40	86.52	87.24

Variety.	Per Cent of the Total Crop.
H 146	0.81
Rose Bamboo	0.78
Yellow Bamboo	0.45
White Bamboo	0.17
H 20	0.15
H 227	0.04
	2.40

Composition of Cane by Islands.

This is shown in Table 2. As in previous years Maui leads in quality of cane with 15.29 polarization of the cane and 88.9 purity of the first mill juice. This purity is higher than that of the last two years and with the exception of 1917, the polarization is higher than any year since 1913. Oahu comes next with 13.75 polarization and 85.40 purity. This polarization is lower than that of last year and the purity is the lowest yet recorded for this island. With the exception of 1917, the cane on Hawaii was better than for several years. On Kauai the polarization was lower than any year except 1918. The purity was lower than any year except 1918 and 1919.

For the whole group the quality of the cane was lower than in any year except 1918. Reference to Table 9, however, shows that excluding the plantations affected by the strike, compared with last year, there was an increase of 0.4 in the purity of the first mill juice, a slight increase in the polarization of the cane and a slight increase in fiber.

Milling.

The quality of the milling work was better than in any previous year. Some additions have been made to the milling equipment. These include adding a shredder and crusher to a nine-roller train, a crusher to a twelve-roller train, a shredder to a crusher and twelve-roller mill, adding a fourth mill to a crusher and nine-roller mill and adding a fifth mill to a crusher shredder and twelve-roller mill. All of these factories have benefitted in extraction because of the additions made.

The improvement in the milling work, however, has not been confined to these factories alone but has been general, 64% of the factories reporting a lower milling loss than last year. The average extraction has increased from 97.30 to 97.45 and the milling loss, or sugar lost per hundred fiber in the bagasse decreased from 2.97 to 2.75, though the cane was of slightly lower polarization, materially higher fiber content and a smaller amount of maceration was used. A further improvement is the reduction in the moisture content of the bagasse from 41.57 to 41.05.

In the factories unaffected by strike conditions, the improvement is much greater. In this case the extraction has increased by .34% and the milling loss decreased by .37%. In these factories the maceration increased slightly over the amount used last year.

In Table 3, the factories are arranged in the order of their milling loss. Two factories, Olowalu and Makee reduced this figure to less than half of what it was last season. Factories that have materially improved their standing in the tabulation are Olowalu, Makee, Pioneer, Hawaiian Sugar, Kekaha, McBryde, Kilauea

TABLE NO. 3.—MILLING RESULTS.

Showing the Rank of the Factories on the Basis of Milling Loss.

Factory	Milling Loss	Extraction Ratio	Extraction	Equipment
1. Maui Agr......	1.27	0.08	99.05	K(2),21RM66
2. Onomea	1.41	0.11	98.61	2RC60,S54,12RM66
3. Hilo	1.50	0.11	98.49	K,2RC60,12RM66
4. Hakalau	1.57	0.12	98.41	2RC54,12RM9-60,3-66
5. H. C. & S. Co...	1.62	0.10	98.92	K(4),2RC78(2),S72(2),12RM78(2)
6. Pepeekeo	1.90	0.15	98.13	2RC54,9RM60
7. Waimea	1.96	0.16	98.31	2RC48,12RM42
8. Olowalu	2.08	0.15	98.06	K,3RC48,9RM48
9. Paauhau	2.21	0.17	97.53	2RC60,12RM66
10. Kilauea	2.38	0.20	97.32	K,S,3RC60,9RM60
11. McBryde	2.45	0.19	97.45	K,S54,9RM84
12. Haw. Sug......	2.48	0.17	97.98	K,2RC72,S72,12RM78
13. Honomu	2.50	0.19	97.59	2RC60,9RM60
14. Pioneer	2.62	0.17	98.12	K,2RC72,S72,15RM72
15. Waianae	2.62	0.18	97.74	K,12RM60
16. Lihue	2.63	0.21	97.25	K,2RC72,S72,12RM78
17. Haw. Agr.	2.67	0.22	97.00	3RC60,12RM66
18. Makee	2.75	0.22	96.95	K,2RC72,S72,9RM72
19. Kekaha	2.86	0.21	97.62	2RC54,9RM60
20. Olaa	2.95	0.23	96.94	K,S72,12RM78
21. Laupahoehoe ..	2.97	0.22	97.14	K(2),11RM60
22. Kahuku	2.98	0.24	96.29	3RC60,S54,9RM72
23. Wailuku	3.00	0.21	97.24	K,2RC72,12RM78
24. Koloa	3.02	0.24	96.68	K,2RC60,12RM66
25. Waialua	3.03	0.23	97.04	K(2),14RM78
26. Oahu	3.08	0.21	97.50	K(2),2RC78(2),S72,12RM78(2)
27. Ewa	3.12	0.24	97.08	K(2),20RM78
28. Hutchinson	3.29	0.28	96.51	2RC60,9RM60
29. Honokaa	3.32	0.27	95.88	K(2),14RM2-60,12-66
30. Kaiwiki	3.56	0.27	96.34	K(2),11RM60
31. Kohala	3.64	0.27	96.45	K(2),S42,11RM60
32. Honolulu	3.68	0.26	96.65	K(2),S54,11RM78
33. Lihue, Han.....	3.70	0.29	96.01	K,2RC72,9RM78
34. Waiakea	3.93	0.31	95.81	K,S42,11RM60
35. Hamakua	4.09	0.32	95.47	K,2RC60,12RM60
36. Hawi	4.10	0.29	96.18	K(3),3RC48,12RM3-48,9-54,S42,9RM54
37. Kaeleku	4.70	0.38	94.78	K(2),11RM2-54,9 60
38. Halawa	7.47	0.56	92.58	K,2RC60,6RM50
39. Union Mill	8.40	0.65	90.29	K,9RM60
40. Kipahulu	10.89	0.82	88.65	K,5RM3-42,2-54
41. Niulii	12.1	0.87	89.09	K(2).9RM54

and Lihue. Those that have lost materially in relative rank are Ewa, Wailuku, Koloa, Olaa, Honakaa, Honolulu, Kaeleku and Waiakea. As has been pointed out before, a considerable improvement in the work from year to year is necessary for a factory to maintain its relative rank. Five factories have dropped from one to three places, though actually doing better work than last year.

Maui Agricultural Co. has again set a new record for milling loss, 1.27, though the extraction is identical with that of last year. For the first time too a factory equipped with a nine-roller mill and crusher, Pepeekeo, has finished a season with over 98 extraction and a milling loss under 2.0. The following table shows the improvement in milling during the past four seasons.

Milling Loss	No. of Factories			
	1917	1918	1919	1920
Under 1.5	0	2	2	2*
" 2.0	3	6	6	7
" 3.0	15	19	20	22
" 4.0	25	28	29	34
Over 4.0	14	9	10	7
Factories reporting	39	37	39	41

* A third factory exactly 1.5.

This year we have an excellent opportunity to compare a twelve and fifteen-roller mill working under practically identical conditions. The mills at Puunene have been so arranged that they can be operated either as two twelve-roller tandems or one fifteen. This season 20% of the crop was grounded with the fifteen-roller set. A similar comparison can be made at Pioneer, where the mill has been increased from twelve to fifteen rollers. In this case, however, the comparison is not so direct as the work of two different seasons must be compared and other changes have been made. In both cases the mill is preceded by a two-roller crusher and shredder. The comparisons follow:

	Puunene		Pioneer	
	12-Roller	15-Roller	12-Roller (1919)	15-Roller (1920)
Tons cane per hour	53.33	77.53	56.29	61.40
Tonnage ratio	1.51	1.84	1.88	1.71
Fiber % cane	10.44	10.74	11.42	11.01
Dilution	48.82	30.14	36.34	31.96
Extraction	98.90	98.98	97.45	98.12
Milling loss	1.70	1.44	3.38	2.62

In both cases the comparison is very favorable to the longer train.

TABLE NO. 4.

GRAVITY SOLIDS AND SUCROSE BALANCES.

Factory	GRAVITY SOLIDS PER 100 GRAVITY SOLIDS IN MIXED JUICE				SUCROSE PER 100 SUCROSE IN MIXED JUICE			
	Press Cake	Commercial Sugar	Final Molasses	Undetermined	Press Cake	Commercial Sugar	Final Molasses	Undetermined
H. C. & S. Co.	4.4	79.0	12.5	4.1	0.5	91.4	5.6	2.5
Oahu	3.6	77.7	14.6	4.1	0.2	91.5	7.0	1.3
Maui Agr.	4.3	80.0	15.7	..	0.3	92.2	7.4	0.1
Pioneer	2.8	79.2	15.2	2.8	0.2	91.2	6.8	1.8
Waialua	2.0	70.4	20.0	7.6	0.4	82.9	10.0	6.7
Haw. Sug.	3.5	80.2	14.4	1.9	0.6	92.3	6.1	1.0
Onomea	5.8	78.5	13.8	1.9	0.1	92.8	5.8	1.3
Hakalau	4.3	77.0	15.1	3.6	0.2	89.8	6.9	3.1
Hilo	4.3	78.1	14.9	2.7	0.2	90.7	6.2	2.9
Wailuku	3.1	79.8	15.0	2.1	0.1	92.2	6.9	0.8
Haw. Agr.	3.9	78.1	16.4	1.6	0.1	90.3	7.5	2.1
Makee	2.5	69.3	21.5	6.7	0.6	83.8	10.6	5.0
Pepeekeo	4.4	79.1	13.9	2.6	0.1	92.9	5.7	1.3
Paauhau	5.8	75.8	16.6	1.8	0.3	91.7	7.6	0.4
Honomu	4.8	78.9	14.4	1.9	0.3	91.9	6.1	1.7
Hutchinson	3.3	80.2	12.8	3.7	0.1	92.0	6.1	1.8
Kohala	7.4	74.6	17.9	0.1	0.2	91.0	8.5	0.3
Kilauea	3.8	69.6	25.3	1.3	0.4	85.8	12.9	0.9

Boiling House Work.

The boiling house work has not been as satisfactory as the milling. The clarification, judging from the increase in purity from mixed juice to syrup, has been less satisfactory than in previous years. This increase, 1.33, is less than in any of the seven years during which this figure has been averaged. Approximately one-half of the factories report a larger increase than last year. The smaller increase reported by the remaining factories, however, brings the average down to the above figure. A smaller amount of lime has been used but it seems hardly probable that this decrease has been enough to materially affect the clarification.

Starting with a mixed juice purity lower than ever before, the smaller increase in purity has resulted in a syrup half a per cent lower than the previous low point reached last year. The increased amount of non-sugar adds to the duty imposed on the boiling house equipment and some allowance must be made for this in commenting on the quality of the boiling house work.

Considering only the factories not affected by strike conditions, we find that the purity of the mixed juice was slightly higher than a year ago. Here too, however, the increase in purity is smaller and the result is a syrup of approximately the same purity as last year.

The filter press work is also less satisfactory than before. For a number of years there has been a more or less gradual increase in the amount of press cake. This year, however, the press cake per 100 cane has increased from 2.32 to 2.63%, a very considerable increase. During the previous four seasons there has been a decrease in the polarization of the cake which has more than offset the increase in quantity and has resulted in a constantly decreasing loss. Three-quarters of the factories report an increased quantity of cake over last year, while about half of factories report an increase in the polarization.

No reasonable explanation for this sudden increase both in quantity and polarization occurs to the writer at the present time. There seems, however, to be some connection between the increased amount of press cake and the smaller increase in purity from mixed juice to syrup. Twelve out of eighteen factories reporting a larger amount of press cake report a smaller increase in purity compared with last year, while eleven out of nineteen factories reporting less press cake report a greater increase in purity. This suggests the possibility that a greater amount of cush cush has been allowed to pass the mill screens and has had a deleterious effect on the clarification.

The evaporation too has been less satisfactory than formerly. Though less maceration was used, resulting in a smaller quantity of mixed juice per cent cane than last year, the density of the syrup was lower than in any year since 1914. The amount of water evaporated per ton of cane was smaller than during the two preceeding seasons. There is a material heat economy in concentrating the syrup to as high a density as practicable in the evaporators. This point is not below 65 brix except possibly for the part of the syrup that is held over night in factories operating only in the day time.

Eliminating the figures from factories affected by the strike does not change the above conclusions either in regard to filter press work or evaporation, except that in the remaining factories a somewhat increased amount of maceration was

TABLE NO. 5.

APPARENT BOILING HOUSE RECOVERY.

Comparing percent. available sucrose in the syrup (calculated by formula) with percent. polarization actually obtained.

Factory	Available *	Obtained	Recovery on Available
H. C. & S. Co.	92.76	92.73	100.0
Oahu	90.48	92.35	102.1
Ewa	87.21	86.23	98.9
Maui Agr.	92.72	92.44 †	99.7
Pioneer	92.33	91.46	99.1
Waialua	88.36	89.07	100.8
Haw. Sug.	93.06	93.47	100.4
Olaa	91.57	90.25	98.6
Onomea	93.37	93.01	99.6
Hakalau	92.13	90.13	97.8
Kekaha	92.14	90.20	97.9
McBryde	89.48	86.49	96.7
Hilo	93.57	90.99	97.2
Wailuku	92.04	92.89	100.9
Haw. Agr.	92.57	90.78	98.1
Lihue	87.50	84.92	97.1
Lihue, Han.	88.53	87.94	99.3
Waiakea	89.93	86.63	96.3
Makee	87.18	84.90	97.4
Honokaa	90.12	88.30	98.0
Laupahoehoe	93.43	91.06	97.7
Pepeekeo	93.40	93.50	100.1
Kahuku	87.07	82.84	95.1
Koloa	89.18	86.22	96.7
Hamakua	88.81	82.96	93.4
Hawi	92.37	87.06	94.3
Paauhau	91.37	91.92	100.6
Honomu	93.60	92.41	98.7
Hutchinson	92.08	92.45	100.4
Kaeleku	86.74	87.36	100.7
Kohala	92.27	90.82	98.4
Kaiwiki	91.45	89.45	97.8
Waianae	89.94	86.70	96.4
Kilauea	86.22	86.88	100.8
Niulii	90.36	83.75	92.7
Halawa	89.17	82.78	92.8
Union Mill	86.82	87.75	101.1
Olowalu	88.85	85.00	95.6
Waimea	90.03	88.12	97.9
Kipahulu	91.89	88.12	95.9

* In order to calculate the available sucrose it is necessary to estimate the gravity purity of the syrup and sugar. Data from factories determining both apparent and gravity purities indicate that the average correction necessary is the addition of 0.8 to the apparent purity of the syrup and 0.3 to the apparent purity of the sugar. When the moisture in the sugar has not been reported 1% has been taken. 38 has been used when the gravity purity of the molasses has not been reported.

† Sucrose.

used, necessitating increased evaporation to bring the syrup to the same density as before.

The polarization of the commercial sugar has remained approximately the same as it was the previous year.

This year the gravity purity of the final molasses has increased from 37.95 to 38.75. Eighty-five per cent of this increase has been due to poorer results in the factories affected by the strike.

During the preceeding two seasons the attention given the low grade work resulted in a very satisfactory reduction in the purity of the final molasses, though the average purity attained was far from the possible limit. However, last year, the loss in molasses was lower than it had been for several seasons, notwithstanding the fact that the syrup purity was the lowest recorded up to that time.

This year the loss in molasses is the largest yet reported. The decreased purity of the syrup is largely responsible for this. In most of the factories affected by the strike, due to delay in harvesting, juices were of low purity and the low grade equipment was overloaded. The average molasses purity reported from the remaining factories, however, has shown no improvement, in fact reference to Table 9 shows an apparent increase. This increase is due to the fact that four small factories, producing high purity molasses, have this year reported molasses losses for the first time. This has influenced the average almost exactly to the extent of the above-mentioned increase shown in Table 9.

That the importance of this work may not be underestimated, the writer would call attention to the fact that with syrup and molasses of about the present purity a decrease of one per cent in the purity of the final molasses means an increased recovery of slightly under one-half of one per cent.

Gravity Solids and Sucrose Balances.

These balances for the factories reporting the necessary data appear in Table 4. These data have been received from eighteen factories, the same number as last year.

Boiling House Recovery.

These Tables, 5 and 6, are to a large extent a check on the chemical control. Table 5 shows the boiling house recovery, based on polarization, compared with the theoretical recovery on the same basis. In calculating this table it is necessary to make certain assumptions explained in the foot note under the table. On account of these assumptions being based on averages the available may vary in individual cases. Comparison of the recoveries, however, based on polarization and sucrose, over a period of years indicates that the figure for recovered on available in Table 5 is probably in all cases within one per cent of the truth. Should this figure then appear as 101% or over it is practically certain that there have been errors in the control. A figure of 99% or under may indicate errors in the control or an actual loss.

For the factories furnishing the necessary data the more reliable figures based on true sucrose are tabulated in Table 6. There appears to be no reason why the recovery on this basis should be over 100% except for inaccuracies in the control. Eighteen factories have furnished the data necessary for inclusion in this table.

With the laboratory facilities and personnel now available at most of the

TABLE NO. 6.

TRUE BOILING HOUSE RECOVERY.

Comparing percent. sucrose available and recovered.

Factory	Available	Obtained	% Recovery on Available
H. C. & S. Co.	92.88	91.86	98.9
Oahu	90.57	91.68	101.2
Maui Agr.	92.72	92.48	99.7
Pioneer	92.23	91.38	99.1
Waialua	88.34	83.23	94.2
Haw. Sug.	93.12	92.86	99.7
Onomea	93.64	92.89	99.2
Hakalau	92.29	89.98	97.5
Hilo	93.61	90.88	97.1
Wailuku	92.06	92.29	100.3
Haw. Agr.	92.67	90.39	97.5
Makee	87.19	84.31	96.7
Pepeekeo	93.41	92.99	99.6
Paauhau	91.13	91.98	100.9
Honomu	93.55	92.18	98.5
Hutchinson	92.19	92.09	99.9
Kohala	91.71	91.18	99.4
Kilauea	86.55	86.14	99.5

TABLE NO. 7.

PERCENT MOLASSES PRODUCED ON THEORETICAL.

H. C. & S. Co.	76.3	Makee	76.4
Oahu	78.0	Honokaa	90.0
Ewa	96.4	Laupahoehoe	98.2
Maui Agr.	100.5	Pepeekeo	84.1
Pioneer	83.5	Kahuku	81.0
Waialua	80.7	Koloa	90.0
Haw. Sug.	88.2	Hamakua	65.7
Olaa	101.3	Paauhau	89.8
Honolulu	85.5	Honomu	87.9
Onomea	83.4	Hutchinson	76.9
Hakalau	78.9	Kaeleku	84.1
Kekaha	75.4	Kohala	101.4
McBryde	96.0	Kaiwiki	80.1
Hilo	82.9	Kilauea	95.2
Wailuku	89.2	Niulii	81.4
Haw. Agr.	90.3	Olowalu	73.0
Waiakea	78.5		

factories it should be practicable to make the extra determinations necessary for a true surcrose balance and a calculation of the recovery on the same basis, particularly since the simplification of these determinations by Walker's modification. The extra determinations required are sucrose in mixed juice, syrup and sugar. The writer considers it very desirable that the sucrose determination be made so that the uncertainty of estimating the difference between polarization and sucrose will be avoided.

In the Synopsis last year attention was called to the discrepancy between the molasses accounted for at the different factories and the theoretical amount based on gravity solids. Since that time the writer's attention has been called to the fact that a part of the diference is due to the method of determining gravity solids. These are calculated from the brix. The concentration of the non-sugar in the syrup is comparatively low while in the molasses it is high. This difference in concentration affects the brix in such a manner that a somewhat smaller amount of solids than the theoretical will be found in the molasses even if there has been no loss. This, however, does not account for the large variations in the figures from different factories and Table 7 showing the % molasses accounted for on the theoretical has again been included to the end that attention be called to these discrepancies and if possible the cause determined.

Factory Efficiency.

The standing of the factories in the order of their efficiency is shown in Table 8. This table has been rearranged, the milling, boiling house and over all efficiency being shown separately.

The arbitrary standard used in calculating the efficiency on a per centage basis is the same as that used during the two preceeding seasons. It is a factory obtaining 100% extraction, reducing the molasses to thirty gravity purity and having no loss other than molasses. Factories showing a recovery of 101% or more on the theoretical (Table 5) have been omitted from this table.

An interesting fact emphasized by this new arrangement is that as a rule the factories obtaining a high extraction also have a high boiling house efficiency.

Losses in Manufacture.

While there has been a reduction in the loss in bagasse, the gain due to more efficient milling work has been more than offset by the lower recovery in the boiling house. There has been an increase in press cake, molasses and undetermined losses bringing the total to 12.65, a figure higher than any since 1914.

The calculations in this Synopsis have been made almost entirely by Mr. A. Brodie.

TABLE NO. 8.

FACTORY EFFICIENCY.

Showing comparative standing of the plantations on the basis of the entire factory work.

No.	Factory	EFFICIENCY		
		Milling	Boiling House	Over All
1	Onomea	98.61	98.09	96.89
2	Pepeekeo	98.13	98.79	96.65
3	H. C. & S. Co.....	98.92	97.18	96.29
4	Haw. Sug.	97.98	98.02	96.19
5	Maui Agr.	99.05	96.68	95.86
6	Wailuku	97.24	98.07	95.53
7	Paauhau	97.53	97.67	95.43
8	Pioneer	98.12	96.45	94.84
9	Honomu	97.59	96.94	94.82
10	Hilo	98.49	95.63	94.27
11	Hutchinson	96.51	97.23	94.13
12	Hakalau	98.41	95.10	93.75
13	Haw. Agr.	97.00	95.50	92.82
14	Kekaha	97.62	94.92	92.78
15	Laupahoehoe	97.14	95.29	92.74
16	Olaa	96.94	95.35	92.67
17	Waimea	98.31	94.12	92.67
18	Kohala	96.45	95.86	92.59
19	Kilauea	97.32	94.72	92.42
20	Kaiwiki	96.34	94.67	91.49
21	Lihue, Han........	96.01	94.58	91.36
22	Ewa	97.08	93.70	91.23
23	Honokaa	95.88	94.75	91.16
24	Waianae	97.74	92.58	90.59
25	Koloa	96.68	93.01	90.30
26	McBryde	97.45	92.26	90.12
27	Kaeleku	94.78	94.54	89.99
28	Waialua	97.04	92.37	89.97
29	Lihue	97.25	91.75	89.44
30	Makee	96.95	91.85	89.37
31	Olowalu	98.06	90.59	89.03
32	Waiakea	95.81	92.12	88.47
33	Hawi	96.18	91.61	88.46
34	Kahuku	96.29	91.29	88.29
35	Hamakua	95.47	89.43	85.72
36	Kipahulu	88.65	92.10	81.89
37	Halawa	92.58	87.22	80.89
38	Niulii	89.09	86.93	77.64

TABLE NO. 9.

TRUE AVERAGES.

	Factories Not Affected by Strike Conditions 1919	Factories Not Affected by Strike Conditions 1920	All Factories 1920
Cane—			
Polarization	13.58	13.61	13.64
Fiber	12.61	12.63	12.64
Tons per ton sugar	8.03	8.06	8.12
Bagasse—			
Polarization	1.69	1.50	1.56
Moisture	41.28	40.68	41.05
Fiber	56.32	57.16	56.68
Pol. % polarization of cane	2.78	2.44	2.55
Milling loss	3.00	2.63	2.75
Weight % cane	22.38	22.09	22.29
First Mill Juice—			
Brix	18.94	19.16	19.32
Polarization	16.56	16.83	16.85
Purity	87.43	97.83	87.24
"Java ratio"	82.0	80.9	80.9
Mixed Juice—			
Brix	13.46	13.45	13.48
Polarization	11.35	11.37	11.31
Purity	84.36	84.50	83.87
Weight % cane	116.32	116.85	117.35
Extraction	97.22	97.56	97.45
Extraction ratio	0.22	0.19	0.20
Last Mill Juice—			
Polarization	1.79	1.73	1.65
Purity	68.72	68.83	68.20
Maceration % cane	38.69	38.93	39.95
Syrup—			
Brix	61.62	60.98	61.34
Purity	85.71	85.74	85.20
Increase in purity	1.35	1.24	1.33
Press Cake—			
Polarization	1.38	1.60	1.65
Weight % cane	2.29	2.58	2.63
Pol. % polarization of cane	0.23	0.30	0.31
Lime used % cane	0.076	0.072	0.071
Commercial Sugar—			
Polarization	96.31	96.40	96.36
Moisture	1.00	0.96	0.97
Pol. % polarization of cane	88.29	87.61	87.35
Pol. % polarization of juice	90.82	90.02	89.56
Final Molasses—			
Weight % cane	3.01	3.06	3.24
Sucrose % polarization of cane	7.26	7.45	8.03
Sucrose % polariaztion of juice	7.44	7.64	8.24
Gravity solids	86.21	86.82	87.42
Gravity purity	38.26	38.38	38.75

TABLE NO. 10.

SUMMARY OF LOSSES.

FACTORY	POUNDS POLARIZATION PER TON OF CANE						POLARIZATION PER 100 CANE						POLARIZATION PER 100 POLARIZATION OF CANE						Syrup Purity	FACTORY
	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL		
H. C. & S. Co.	3.4	1.4	18.0	...	4.8	27.6	0.17	0.07	0.90	...	0.24	1.38	1.08	0.45	5.65	...	1.50	8.68	86.90	H. C. & S. Co.
Oahu	7.4	0.6	20.4	...	1.6	30.0 *	0.37	0.03	1.02	...	0.08	1.50 *	2.50	0.21	6.93	...	0.51	10.15*	84.8	Oahu
Ewa	7.6	1.2	32.6	...	1.8	43.2	0.38	0.06	1.63	...	0.09	2.16	2.92	0.51	12.62	...	0.68	16.73	81.15	Ewa
Maui Agr.	3.0	0.8	23.0	...	0.4	27.2 †	0.15	0.04	1.15	...	0.02	1.36 †	0.95	0.28	7.35	...	0.12	9.70 †	88.46	Maui. Agr.
Pioneer	5.8	0.6	20.6	...	5.0	32.0	0.29	0.03	1.03	...	0.25	1.60	1.88	0.17	6.70	...	1.66	10.41	86.26	Pioneer
Waialua	8.0	1.2	27.0	...	8.6	44.8	0.40	0.06	1.35	...	0.43	2.24	2.96	0.45	10.06	...	3.23	16.70	83.3	Waialua
Haw. Sug.	5.8	1.8	17.4	...	0.8	25.8	0.29	0.09	0.87	...	0.04	1.29	2.02	0.62	6.06	...	0.30	9.00	86.47	Haw. Sug.
Olaa	7.6	0.8	22.4	...	1.2	32.0	0.38	0.04	1.12	...	0.06	1.60	3.06	0.34	8.94	...	0.48	12.82	86.0	Olaa
Honolulu	9.6	1.0	28.2	...	...	...	0.48	0.05	1.41	...	...	...	3.35	0.35	9.92	...	...	....	85.65	Honolulu
Onomea	3.6	0.2	14.8	...	2.6	21.4	0.18	0.01	0.74	...	0.14	1.07	1.39	0.08	5.77	0.02	1.16	8.26	86.4	Onomea
Hakalau	4.2	0.4	18.2	...	7.6	30.4	0.21	0.02	0.91	...	0.38	1.52	1.59	0.16	6.87	...	2.83	11.45	86.3	Hakalau
Kekaha	6.6	1.2	22.4	...	3.8	34.0	0.33	0.06	1.12	...	0.19	1.70	2.38	0.41	8.14	...	1.39	12.32	86.3	Kekaha
McBryde	6.6	0.2	29.6	...	4.8	41.2	0.33	0.01	1.48	...	0.24	2.06	2.55	0.10	11.35	...	1.80	15.80	84.6	McBryde
Hilo	4.0	0.6	16.6	...	7.2	28.4	0.20	0.03	0.83	...	0.36	1.42	1.51	0.22	6.13	...	2.73	10.59	87.03	Hilo
Wailuku	8.0	0.4	19.6	...	0.4	28.4	0.40	0.02	0.98	...	0.02	1.42	2.76	0.14	6.77	...	0.14	9.81	85.82	Wailuku
Haw. Agr.	7.2	0.2	17.4	...	3.8	28.6	0.36	0.01	0.87	...	0.19	1.43	3.00	0.08	7.34	...	1.60	12.02	86.88	Haw. Agr.
Lihue	6.8	1.0	...	...	36.6	44.4	0.34	0.05	...	...	1.83	2.22	2.75	0.39	...	...	14.61	17.75	82.21	Lihue
Lihue, Han.	10.4	0.8	...	...	29.8	41.0	0.52	0.04	...	...	1.49	2.05	3.99	0.31	...	...	11.55	15.85	82.9	Lihue, Han.
Waiakea	10.8	0.4	22.8	...	10.2	44.2	0.54	0.02	1.14	...	0.51	2.21	4.19	0.19	8.87	...	3.92	17.17	84.86	Waiakea
Makee	7.4	1.6	25.4	...	10.2	44.6	0.37	0.08	1.27	...	0.51	2.23	3.05	0.62	10.39	...	4.16	18.23	81.98	Makee
Honokaa	10.0	0.4	22.6	...	4.6	37.6	0.50	0.02	1.13	...	0.23	1.88	4.12	0.16	9.30	...	1.96	15.50	83.66	Honokaa
Laupahoehoe	7.8	0.4	20.0	...	3.4	31.6	0.39	0.02	1.00	...	0.17	1.58	2.86	0.12	7.40	...	1.27	11.65	87.85	Laupahoehoe
Pepeekeo	4.8	0.4	14.4	...	2.0	21.6	0.24	0.02	0.72	...	0.10	1.08	1.87	0.13	5.58	...	0.78	8.36	86.17	Pepeekeo
Kahuku	9.2	0.4	28.8	...	12.2	50.6	0.46	0.02	1.44	...	0.61	2.53	3.71	0.17	11.60	...	4.89	20.37	79.86	Kahuku
Koloa	8.4	0.6	27.0	...	6.8	42.8	0.42	0.03	1.35	...	0.34	2.14	3.32	0.25	10.60	...	2.69	16.86	82.5	Koloa
Hamakua	11.6	0.4	22.4	...	19.4	53.8	0.58	0.02	1.12	...	0.97	2.69	4.53	0.17	8.71	...	7.53	20.94	82.54	Hamakua
Hawi	11.0	1.0	...	...	35.6	47.6	0.55	0.05	...	...	1.78	2.38	3.82	0.34	...	...	12.40	16.56	86.26	Hawi
Paauhau	6.2	0.8	19.0	...	1.0	27.0	0.31	0.04	0.95	...	0.05	1.35	2.47	0.32	7.50	...	0.36	10.65	84.8	Paauhau
Honomu	6.4	0.8	15.8	...	3.8	26.8	0.32	0.04	0.79	...	0.19	1.34	2.41	0.31	5.98	...	1.40	10.10	86.9	Honomu
Hutchinson	8.4	0.2	14.2	...	3.2	26.0	0.42	0.01	0.71	...	0.16	1.30	3.49	0.10	5.92	...	1.36	10.87	86.8	Hutchinson
Kaeleku	12.8	1.0	25.8	...	3.4	43.0	0.64	0.05	1.29	...	0.17	2.15	5.22	0.44	10.50	...	1.42	17.58	81.87	Kaeleku
Kohala	9.6	0.6	22.0	...	1.8	34.0	0.48	0.03	1.10	...	0.09	1.70	3.55	0.19	8.19	...	0.65	12.58	86.3	Kohala
Kaiwiki	9.8	0.8	19.8	...	7.2	37.6	0.49	0.04	0.99	...	0.36	1.88	3.66	0.29	7.41	...	2.72	14.08	85.2	Kaiwiki
Waianae	6.4	1.0	...	...	37.0	44.4	0.32	0.05	...	...	1.85	2.22	2.26	0.36	...	...	12.95	15.57	84.14	Waianae
Kilauea	6.2	0.8	29.6	...	...	36.6	0.31	0.04	1.48	...	...	1.83	2.68	0.28	12.70	...	0.09	15.78	81.1	Kilauea
Waimanalo	...	2.4	...	...	...	...	...	0.12	...	...	...	...	...	...	...	...	...	....	....	Waimanalo
Niulii	30.4	2.2	26.4	...	13.8	72.8	1.52	0.11	1.32	...	0.69	3.64	10.91	0.76	9.42	...	1.94	26.03	87.7	Niulii
Halawa	19.8	0.6	...	...	42.4	62.8	0.99	0.03	...	...	2.12	3.14	7.42	0.32	...	...	15.90	23.54	85.73	Halawa
Union Mill	25.2	1.8	...	...	28.4	55.4 *	1.26	0.09	...	...	1.42	2.77 *	9.71	0.68	...	...	10.98	21.37 *	83.58	Union Mill
Olowalu	5.6	0.6	26.4	...	15.2	47.8	0.28	0.03	1.32	...	0.76	2.39	1.94	0.22	9.33	...	5.35	16.84	84.44	Olowalu
Waimea	4.2	1.4	...	...	28.8	34.4	0.21	0.07	...	...	1.44	1.72	1.69	0.59	...	...	11.61	13.89	83.50	Waimea
Kipahulu	30.6	3.2	...	...	27.6	61.4	1.53	0.16	...	...	1.38	3.07	11.43	1.23	...	...	10.30	22.96	85.81	Kipahulu

* A comparison of the available sucosre in the juice with the amount recovered in the boiling house indicates that there is probably an error in some of the results reported from this factory.

† Sucrose.

THE HAWAIIAN PLANTERS' RECORD

Volume XXIV. FEBRUARY, 1921 Number 2

A monthly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

H 109 Gives the Highest Yields.

OAHU SUGAR COMPANY, EXPERIMENT NO. 5, 1920 CROP.

In this experiment the following varieties of cane were compared: H 109, H 456, Striped Mexican, and Badila. H 146, H 227, Yellow Caledonia, and Lahaina were also included in the experiment, but they did not do well and on account of the lateness of the season and difficult labor conditions they were not harvested as part of the test. H 146, which did so well in this field two years ago as plant cane, has since developed Lahaina disease and is not to be recommended for any regions where Lahaina disease is likely to be present.

This crop was first ratoons, long, being the second crop from virgin land. The field is at about 550 feet elevation and irrigated with mountain water.

The 1918 crop was harvested in March, 1918, and the ratoons cut back on July 7, 1918. The Badila was not cut back.

The 1920 crop was harvested in November, 1920, the cut-back varieties being 28 months old and the Badila 31 months. From January, 1920, to the time of harvest this field was not irrigated and was rather dry at time of cutting. The rainfall during this period amounted to 23 inches, but with the exception of 5.40 inches in January and 5.07 inches in March, none of this rain was in sufficient quantity at any one time to be of any great value to big cane—that is, all the other rains were of less than half an inch each.

The results obtained from the different varieties were as follows:

Variety	Yield per Acre (Tons)		
	Cane	Q. R.	Sugar
H 109	97.39	7.61	12.80
H 456	76.61	7.26	10.55
Striped Mexican	79.20	7.58	10.45
Badila	79.89	8.47	9.43

The H 109 produced over two tons of sugar per acre more than any other variety. H 456 was second in yield and had the best juices. It is well to note here that H 456 was plant cane, having replaced H 333 on account of eyespot on the latter variety. The planting was done on June 26, 1918. The old stools were dug out by hand and the seed put down in the same place. No plowing was done. Body seed was used, some of which was very hard. The seed germinated very slowly and very poorly. On account of lack of seed it was impossible to do any replanting. As a result the stand was poor. When comparing the results obtained this slower start and poor stand should be borne in mind. The Badila did not do very well on these upper lands. It was probably too old when harvested. At time of harvest Badila had the poorest juice of the lot; there was also a considerable amount of dead cane.

Although not in this experiment, D 1135 in adjoining tests gave yields very nearly as good as the H 109. The quality of the D 1135 juices was remarkably good, better than Lahaina juices in adjoining plots receiving similar treatment.

J. A. V.

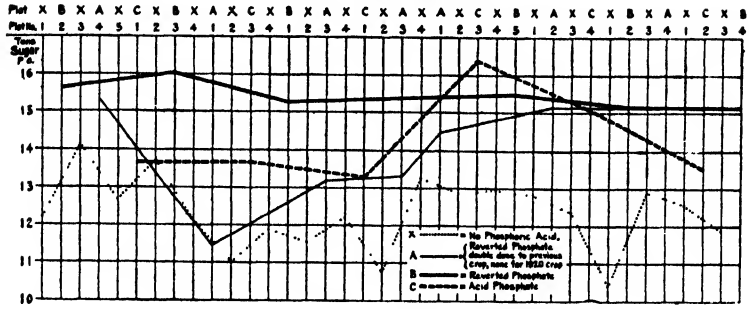
Phosphoric Acid for the Upper Lands on Oahu.

OAHU SUGAR COMPANY, EXPERIMENT NO. 6, 1920 CROP.

SUMMARY.

In this experiment a study was made of the value of different forms of phosphoric acid in addition to nitrogen for the upper lands (550 feet elevation) of Oahu. The crop was H 109, first ratoon, long. This is the second crop raised on these lands, the plant crop having been from virgin land.

CHART SHOWING YIELDS BY PLOT FOR EACH TREATMENT.
OAHU SUGAR CO. EXP. 6, 1920 CROP



The treatments were as follows: all plots received 175 pounds of nitrogen per acre, applied in four equal doses, in August and November, 1918, and February and May, 1919. In addition to this the A plots received 1143 pounds per acre of reverted phosphate (180 pounds of P_2O_5) for the 1918 crop. This was intended to last for two crops. No phosphate was added to the A plots for the 1920 crop. The B plots received 643 pounds of reverted phosphate (90 pounds P_2O_5), while the C plots received 474 pounds of acid phosphate (90 pounds P_2O_5).

The results obtained from the two crops, one plant and one long ratoons, are given as follows:

1918 CROP — PLANT.*

Plots	Treatment	Yield per Acre			Gain Over No Phosphoric Acid	
		Cane	Q. R.	Sugar	Cane	Sugar
X	No phosphoric acid	67.38	9.53	7.07	...	...
A	180 lbs. P_2O_5 from reverted phosphate	75.45	9.62	7.84	8.07	0.77
B	90 lbs. P_2O_5 from reverted phosphate	75.85	9.28	8.17	8.47	1.10
C	90 lbs. P_2O_5 from acid phosphate	80.88	9.63	8.40	13.50	1.33

* For details of the 1918 crop see Planters' Record, Vol. XIX, page 142.

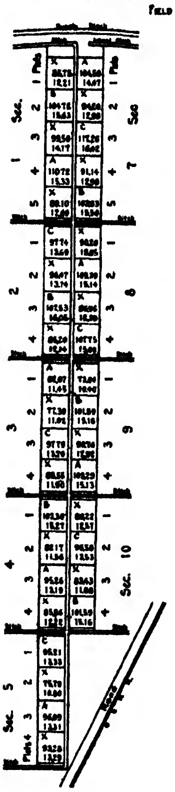
1920 CROP — FIRST RATOON, LONG.

Plots	Treatment	Yield per Acre			Gain Over No P_2O_5	
		Cane	Q. R.	Sugar	Cane	Sugar
X	No phosphoric acid	86.9	7.02	12.38	...	...
A	No phosphoric acid 1920 crop; 180 lbs. P_2O_5 1918 crop	101.1	7.22	14.01	14.2	1.63
B	90 lbs. P_2O_5 from reverted phosphate	103.1	6.70	15.46	16.2	3.08
C	90 lbs. P_2O_5 from acid phosphate	102.1	7.14	14.29	15.2	1.91

The A and B plots received the same amount of P_2O_5 from reverted phosphate for the two crops, but in the case of the A plots it was all applied to the plant cane, and none to the ratoons; for the B plots the P_2O_5 was equally divided between the plant and ratoons. Dividing it between the two crops gave the best results for both crops.

There was very little difference in the yield of cane from the different series of plots receiving phosphoric acid. But it is interesting to note that for both crops, the B plots getting 90 pounds of P_2O_5 per acre from reverted phosphate had the better juices, thereby producing the most total sugar.

FORMS OF PHOSPHORIC ACID.
OAHU SUGAR CO. EXP 6, 1920 CROP
FIELD 45



SUMMARY OF RESULTS

Plots	No. of Plots	Treatment	Yields Per Acre: Cane	Yields Per Acre: Q.R.	Yields Per Acre: Sugar	Gain Over No P_2O_5: Cane	Gain Over No P_2O_5: Sugar
X	19	No Phosphoric Acid.	86.94	7.02	12.38	-	-
A	7	No Phosphoric Acid 1920 Crop 180 Pounds P_2O_5 1918 Crop.	101.12	7.22	14.01	14.18	1.63
B	6	90# P_2O_5 From Reverted Phosphate.	103.09	6.70	15.46	16.15	3.08
C	6	90# P_2O_5 From Phosphoric Acid	102.05	7.14	14.29	15.11	1.91

DETAILS OF EXPERIMENT.

1. Reverted phosphate.
2. Super-phosphate.
3. No phosphate.

Object—To determine the value of applying reverted phosphate as against applying acid phosphate or no phosphate.

Location—Oahu Sugar Company, Field 45, Koalipea Section, Division No. 1, on both sides of the straight ditch that runs through the experimental area of the field.

Crop—H 109, first ratoon, long.

Layout—No. of plots, 38.

Size of plots, each 1/22 acre (36'x 55'), consisting of 10 single rows, each 5.5' wide and 36' long. Each plot 1 watercourse in width. Each single row 1/220 acre. These areas include watercourses. For level ditches and straight ditches add 2.5%.

Plan—"A" plots = 180 pounds per acre of P_2O_5 as reverted phosphate applied before planting the last crop. (To last for two crops.)

"B" plots = 90 pounds per acre of P_2O_5 as reverted phosphate, applied August, 1918.

"C" plots = 90 pounds per acre of P_2O_5 as acid phosphate, applied in two equal doses (August, 1918, and November, 1918).

"X" plots = No phosphoric acid.

All plots to receive 175 pounds per acre of nitrogen in four doses, as follows:

244 pounds per acre of N.M. August, 1918.
244 pounds per acre of N.M. November, 1918.
244 pounds per acre of N.M. February-March, 1919.
241.6 pounds per acre of N.M., May-June, 1919.

N.M. = Nitrogenous mixture: 18% nitrogen—½ sulfate of ammonia and ½ nitrate of soda.

Detail of Work—

1918 crop harvested in March, 1918.
1920 crop cut back July 7, 1918.
First fertilization August 31, 1918, by Kutsunai.
Second fertilization November 8, 1918, by Kutsunai.
Third fertilization February 19, 1919, by Kutsunai.
Fourth fertilization May 26, 1919, by Kutsunai.

Experiment harvested in November, 1920, by Kutsunai, Pauhau, with Kabori helping. All juices sampled at crusher in carload lots by Bomonti.

J. A. V.

The Mineral Requirements of Plants.*

By H. F. BERGMAN.

All plants require for their normal development certain chemical elements such as carbon, hydrogen, oxygen, nitrogen, potassium, phosphorus, sulphur, magnesium, calcium, and iron. All of these are not used to an equal extent, but no one of them may be lacking without in some way interfering with the normal development of the plant. Of these elements only one, oxygen, is capable of being absorbed in a free or elemental state. The others are absorbed as chemical compounds which must be soluble in water in order to be taken into the plant. In general they occur and are absorbed as nitrates, phosphates, sulphates, and carbonates. The plant shows no preference among these forms in absorbing materials provided that all the essential elements are supplied.

Carbon is very widely distributed in nature, occurring as carbon dioxide in the atmosphere and as *carbonates* in the soil. It is the most abundant constituent of the dry matter of the plant, making up by far the greater part of the dry weight. All the carbon in the plant body is taken from the atmosphere. Although carbon exists in the soil as carbonate and is absorbed by the plant, the *carbon* in such absorbed *carbonates* is not utilized in building up the *carbonaceous* matter of the plant body.

In the atmosphere there is present about three or four parts of carbon dioxide in ten thousand parts of air. Yet it is from such a dilute mixture that all the carbonaceous material in the dry matter of the plant is built up. When we consider that for each ton of green plant material 80-90 per cent is water and of the remaining 10-20 per cent the larger part of it is carbon, we may get some

* A lecture presented at the Short Course for Plantation Men, October, 1920.

idea of the immense volume of air required to supply this amount of carbon. Of these two most extensively used materials, water and carbon dioxide, there is fortunately an abundant supply, so that they are not often lacking.

The carbon dioxide of the atmosphere is absorbed by the leaves and green parts of stems through microscopic openings, called stomata, which occur in the epidermis. In a very large number of plants the stomata occur only on the under side of the leaves. Some plants have stomata on both upper and lower sides. In some instances the distribution is equal, in others there may be more on the lower side than on the upper, and in a few cases the greater number appears on the upper surface.

The air enters the stomata, after which it comes in contact with the moist walls of the cells in the interior of the leaf. It then goes into solution in the water and passes through the cell wall into the cell. There occur within the cells of the leaf green bodies or chloroplasts which in the presence of light have the ability of combining the carbon of the absorbed air with water to form carbohydrates. The reaction in its simplest form may be indicated as follows:

$$CO_2 + H_2O \rightarrow CH_2O + O_2$$

The product CH_2O is *formic aldehyde* and is regarded as the first step in the formation of carbohydrates. By combining several molecules (polymerization) a more complex molecule is formed. Thus if six molecules of CH_2O were combined into one we would have $C_6H_{12}O_6$, which is known as glucose, dextrose or grape sugar. If two molecules of glucose are combined and one molecule of water abstracted we have $C_{12}H_{22}O_{11}$, or cane sugar. The plant is able to make the simple combination first indicated, and then by polymerization to make the more complex substances *glucose* and cane sugar or starch. Starch is similar in composition to glucose, the most commonly assigned formula being $(C_6H_{10}O_5)$ *N*.! By adding a molecule of water, starch may be converted into glucose, $C_6H_{12}O_6$.

It will be seen that for each molecule of carbon dioxide taken in, one molecule of water is required, and one molecule of CH_2O is formed with the liberation of one molecule of oxygen. Or if we consider starch as the final product the reaction might be indicated as follows:

$$6\ CO_2 + 5\ H_2O \rightarrow C_6\ H_{10}O_5 + 6\ O_2$$

For each molecule of starch six molecules of carbon dioxide are required with the liberation of six molecules of oxygen. This process of carbon assimilation, or photosynthesis, can take place only in green parts of the plant and only in the presence of light. The hydrogen and oxygen used in the formation of carbohydrates is derived from water, and it will be observed by reference to the equations given above that hydrogen and oxygen are always combined in the proportion in which they occur in water. The water used in this process is absorbed from the soil by the roots.

The materials so far considered are used in the formation of carbohydrates. In addition to these every plant must be supplied with nitrogen in some form for the formation of proteids. Proteid substances constitute the bulk of the protoplasmic material of which the plant consists. In addition to carbon, hydro-

gen and oxygen, all proteids contain nitrogen and sometimes also phosphorus and sulphur. Nitrogen also appears in other compounds present as plant constituents.

Although nitrogen makes up about four-fifths of the volume of the air and is absorbed by the plant with other constituents of the air, none of this atmospheric nitrogen can be utilized by plants. All the nitrogen necessary for plant metabolism is taken up from the soil as nitrates or as ammonia or other compounds readily convertible into nitrates. The higher or flowering plants cannot utilize nitrogen to any extent except as nitrates. This applies even in the case of leguminous plants. These indirectly make use of atmospheric nitrogen, and for this reason are valuable for adding nitrogen to the soil. The bacteria in the nodules on the roots of leguminous plants convert free nitrogen into ammonia compounds, then to nitrites and finally into nitrates, thus making the nitrogen available to the plants on the roots of which the nodules occur.

Proteid formation, like carbohydrate synthesis, takes place largely in the leaves, although, unlike the latter, it is not dependent on light nor is the action of the chloroplasts necessary. Proteid formation goes on at night as well as in daylight, and may occur in any part of the plant. The localization of this process in the leaves is probably due to the fact that an abundant supply of carbohydrate material is present from which proteids may be synthesized.

The remaining elements are the so-called ash constituents, since they are left when the plant is burned. Of these, phosphorus and sulphur are used in the formation of proteids of which the protoplasmic substance is built up. The nucleus of cells is especially rich in phosphorus.

Phosphorus must be in the form of phosphates to be available to the plant. The primary and secondary phosphates are more soluble than the tertiary, and hence are more readily available. On account of their greater solubility the primary and secondary phosphates are more apt to be leached out of soils by heavy rains. For this reason it is sometimes better to apply tertiary phosphate when a deficiency of this element exists. This is sufficiently soluble, especially when carbon dioxide is present in the soil water, even to as slight an extent as 0.03 to 0.04 per cent, to supply the requirements of the plants.

Potassium is relatively abundant in young tissues. The exact function of this element is not agreed upon. It may be connected with the formation of carbohydrates and proteins. Evidence indicates that when potassium is not supplied, starch formation does not take place. Similarly, in the absence of potash, proteid formation does not occur even when the plant is supplied with sugar. It has also been shown that seeds or other parts of the plant rich in proteins are also high in potash. Other investigators claim that it is largely concerned with the maintenance of turgor in plant cells. Whatever its exact function may be, it is indispensable and cannot be replaced by sodium or other elements.

The function of calcium and magnesium is likewise not well defined. Magnesium has a distribution and importance somewhat similar to that of potassium, as it occurs abundantly with the latter in young tissues. Its main function is probably in the conveyance of phosphoric acid for assimilation. Magnesium is also utilized along with potassium salts in the maintenance of turgidity. Calcium is in some instances apparently necessary in the formation of cell walls.

Calcium is also commonly present as calcium oxalate in many plants, and therefore one of its functions may be to neutralize the oxalic acid formed in metabolism and thus prevent injury to the plant by the accumulation of this acid. Certain experiments have shown that calcium is in some way necessary for starch digestion, and some later investigators assign to calcium an active function in the formation of certain compounds as a necessary preliminary in the construction of proteins. In spite of the fact that the exact manner in which these elements are used by the plant is not clear, it is well known that if they are not supplied the plant is unable to make normal growth.

Iron, although required in less quantity than many other elements, is highly important to the welfare of the plant. It is necessary for the maintenance of the chlorophyll upon which photosynthesis depends. If iron is not supplied, the plant becomes yellow. In this condition the chloroplasts are inactive and cannot assimilate carbon dioxide. Apparently a plant can make use of any iron compound that is soluble, hence it makes little or no difference as to the form in which iron is supplied.

Certain substances in the soil sometimes nullify the effect of iron in some way. This seems to be true in the case of manganese with pineapples. Where the soil contains a high manganese content the plants are unable to absorb or utilize the iron compounds in the soil, so that they soon become yellow or sickly in appearance. An application of an iron salt, usually sulfate, as a spray on the leaves has been found to be an efficient remedy.

Many substances not necessary to the growth of the plant or usable by it may, however, find their way into the plant in moderate or large quantities. Similarly, the necessary elements may be absorbed in quantities greater than can be used if abundantly present in the soil. Even substances injurious to the plant will be absorbed from the soil if present there in soluble form, as the plant cannot select the desirable materials and exclude others which are not desirable or which are injurious.

All materials in the soil in soluble form are taken in through the epidermis and root hairs on the younger portions of the root by the process of osmosis. Osmosis is the passage or interchange of substances between solutions of unequal concentration separated by a non-porous membrane. By non-porous is meant that there are no openings or pores evident even when examined with the microscope. If an interchange is effected there must be passageways, but these are only of molecular dimension. All substances are composed of molecules, which are constantly in motion and never in contact with each other, so that very minute inter-molecular spaces are present. Substances in solution become separated into molecules or these often dissociate into ions.

In the case of a plant growing in soil, the epidermis is the separating membrane. The soil water with the various dissolved mineral salts constitutes one solution and the cell contents the other. The mineral salts being more abundant outside the plant than inside makes an osmotic interchange possible. In osmosis the interchange is from the more concentrated to the less concentrated solution, and continues in this direction until the concentrations become equalized on both sides of the membrane.

Any substance in the soil if soluble in water may enter the plant ordinarily. The molecules of a substance in solution move about freely, so that some molecules strike the intercellular spaces of the membrane (cell wall), penetrate through these spaces and gain entrance to the cell. This is true regardless of the fact as to whether the entering substance is beneficial, inert or injurious to the plant. After entering the epidermis the substance osmoses from cell to cell and finally reaches every living cell in the entire plant.

If the entering substance is one which is necessary for the growth of the plant it is at once changed into some other form or used up. It is thus thrown out of circulation, so that more substance continues to be absorbed from the outside. This will continue as long as that particular substance is being used by the plant. If supplied more rapidly than the plant can use it, the substance will enter until the concentration of the substance becomes the same in the cell sap as in the soil solution outside. The same would apply to substances for which the plant finds no use except that such materials would not be transformed and would enter only until the concentration within the plant has become equalized with the soil solution with reference to that substance.

The absorption of any given substance may take place independently of the movement of any of the others. Thus, if a plant requires nitrate and nothing else for a time, only nitrates would be absorbed. This is due to the fact that the nitrates upon entering the plant are converted into some other substance. In such a change they lose their identity as nitrates, so that as long as they continue to be transformed the concentration of nitrates in the cells of the plant never reaches that of the soil solution and therefore nitrates continue to be absorbed. This is the so-called "selective absorption" of plants, and means only that substances will be absorbed more or less continuously if needed in the metabolism of the plant, otherwise only until the concentration of these substances inside the plant has become the same as in the soil solution outside. It does not mean that plants can choose substances useful to them and exclude those which are not useful or injurious. The inability of plants to "select" foods in their sense is shown by the fact that if copper or zinc salts are supplied they will be absorbed and result in the death of the plant.

Boiling-house Methods.*

H. S. Walker.

A Committee on Boiling-house Methods was appointed at the 1919 meeting of the Hawaiian Chemists' Association to replace the former Committee on Evaporation and Boiling, Curing and Marketing, and Clarification and Filtration, and to cover in general the entire work of the boiling house.

* Presented at the Eighteenth Annual Meeting of the Hawaiian Chemists' Association, held jointly with the Hawaiian Engineering Association, November, 1920.

Letters were sent out during the summer to the men in charge of this work, and to all the plantations, requesting their cooperation especially along the line of new ideas or new methods tried out during the year. No definite list of set questions was put forth, but the following topics were suggested for discussion:

Clarification—*Effect of temperature.*

Evaporation—Chemical means for removing scale from evaporator tubes.

Boiling—General Methods—It has been suggested that we adopt a standard system of sugar boiling which, of course, would have to be deviated from according to the equipment of individual factories. In order to bring out discussion on this subject, I submit for your criticism the following method, which is a slight modification of the one used at Pioneer for a number of years:

STRIKE 1A: Start on a magma of low-grade sugar and syrup. Build up and finish with syrup and remelt. No molasses boiled in this strike.

STRIKE 1B: Start as for 1A and finish by taking back all the molasses from 1A.

STRIKE 1C: Start as for 1A, and finish by taking back all the molasses from 1B.

STRIKE 2: Boil all the molasses from 1c to grain for the crystallizers.

Stated more briefly, the method consists in making every third strike from straight syrup and remelted sugar, and boiling back all the molasses twice. With syrup purities between 85 and 88 this method works fairly well, yielding a 1c molasses of from 50 to 54 apparent purity without any calculation or attempt to boil to fixed purities. With initial purities below 85, strike 1c may be omitted, as the 1B molasses will be low enough to boil for the crystallizers.

I am not putting this forth as the ideal method; if you do not approve of it, please state why, and why the method used in your own factory is a better one.

Boiling—Low grade—Different methods of graining. Causes and prevention of "false" grain.

Crystallizer work—Time required for complete crystallization; effect of temperature; effect of adding water to a massecuite on the resultant purity of molasses. Is it possible in any way to add water to a low-grade massecuite without raising the purity of the molasses? In other words, if on account of limited centrifugal capacity a factory cannot dry its low-grade massecuite at a higher density than 95° Brix, is there any advantage in boiling to 99° Brix and subsequently diluting to 95°? If so, when and how is the best time to add the water? What advantage is gained by long slow boiling of low grades? Given two massecuites of the same final Brix, purity, and number of grains; if one has taken 24 hours to boil and yields a molasses, separated hot, of 35 apparent purity, while the other was boiled in five hours and yields a separated hot molasses of 42 apparent purity, will there be any difference in the ultimate purity of the two molasses after two weeks in the crystallizers?

The following replies were received:

From Mr. A. Fries, Hawaiian Sugar Co.:

In reply to your request for a contribution to the report of the Committee on Boiling-house Methods, and following your general suggestions, I submit the following:

During the past year no methods of manufacture have been introduced in the operations at Makaweli which differ essentially from those in use at other factories. Some sug-

gestions made at the last meeting of the Hawaiian Chemists' Association have been tried out, with varying degrees of success. What interested me particularly, however, is the differences obtained by identical methods of operation here and during my engagement at Lahaina. I have no theory as to the causes of these differences outside of the variation in the nature of the juices. In this report I shall follow out, as far as possible, comparisons of work in the two places, and believe that this may be of value and interest to your report.

BOILING.

The method outlined in your request for a report is essentially that used by me while at Lahaina, and continued at Makaweli. There are so many points in its favor that they far outweigh the one objection that can be urged against it, viz: the fact that three sugars of different polarizations are turned out. This is a difficulty more for the refinery, but should not be a very serious objection, inasmuch as the sugar received from the factories, as operated now, differs more widely than the sugar from an individual factory operating under this method.

The advantages mainly are:

It gives a system to the whole process of boiling, which is very simple and is readily taken up by the unskilled pan operator.

Less boiling, and consequently a saving of fuel, and also greater capacity in the boiling department. It is well known that more sugar can be turned out under the same conditions of equipment and steam supply when more than one grade of massecuite is boiled to. Or, in other words, it is easier to get rid of a definite quantity of syrup if one boils the first strike to, say, 85; the second to 80, and the third to 78 purity massecuite, than by making all strikes 78 purity.

The taking back and reboiling of molasses is brought to a minimum, as under ordinary conditions every third strike gives a molasses of such purity as to be ready for the crystallizers, which therefore is undoubtedly much less gummy than when all strikes are boiled to 78 purity or lower.

BETTER CRYSTALLIZER WORK.

In the modification of the method Mr. Walker takes all of the molasses from strike two into strike three, and I doubt if this will always work as satisfactorily. Instead of taking all of this molasses back into the next strike, I prefer to limit this amount so that a purity of molasses is obtained which is considered suitable for crystallizer work, as otherwise the purity may come below this set standard, and result in a slower drying sugar, without the compensating lower purity of final molasses.

In respect to the crystallizer strikes, I have noticed a very important difference in the massecuite here at Makaweli and that at Lahaina. Although boiled under the same conditions and of syrup of similar purity, the massecuite is, on the whole, far freer and less viscous than that at Lahaina. We are able to purge the low grades in less time, getting a higher purity melt and a final molasses from two to three points lower in purity. Others have observed that while it is possible to do very good work in one factory, the same sugar boiler will find it impossible to get equal results at some other factory, though equipment and conditions are alike. This is due to the peculiar quality of the juices. Probably the nature of the impurities if better understood would give a more satisfactory explanation.

With the exception of a few weeks at the beginning of the crop, we have been "shock seeding" our low grades. There is no doubt as to the benefit of this method in our case. An even, square grain is obtained which grows rapidly and regularly, and it is only when accidental conditions occur that we get false grain. I do not know whether this method of "shock seeding" operates as actually introducing seed, or whether it is producing a condition of supersaturation, but I am satisfied as to the advantages.

CRYSTALLIZERS.

During the past season we have worked all our low grade in the 16 crystallizers without using the outside tanks. The crystallizers are "U" shaped, and hold 750 to 800 cubic feet under working conditions. The stirrer makes 0.3 revolution per minute, and the massecuite remains from 8 to 12 days.

For this crop we have tried to maintain a Brix of close to 98 in the low-grade massecuite, whenever possible. With inferior juice this cannot always be carried out on account of the sticky nature of the molasses. The improvement in the low-grade work this year is due to the higher density boiled, coupled with a better grain following "shock seeding," and the method of boiling first massecuite, as stated above. Better results are obtained by boiling to a high Brix, and then diluting to a lower Brix after several days in the crystallizers than by dropping the massecuite from the pan at this same low density.

We dilute from 94 to 95 Brix with water, as without it we would have difficulty in purging. With more centrifugal capacity for low grades, and consequently less dilution of the massecuite, better results as to the final molasses could be obtained, as every addition of water increases the purity of this molasses—very slightly, perhaps, when small quantities are used, but considerably when the massecuite is purged at the density of 93 or lower.

Another thing which has contributed to a better exhaustion of the molasses is the slower time of boiling. Since a new pan was put in for handling first massecuites, there have been two pans of about 800 cubic feet capacity each, available for the low grades. This allows nine hours for forming the grain and filling the pan, and four hours for building up after cutting, or a total of 13 hours. I should judge that a massecuite boiled for 24 hours could be boiled at a much lower temperature than one struck in five hours, and that after 10 days the former will not only yield a lower molasses, but will dry much more readily.

The following table gives an average of the season's crystallizer work:

CRYSTALLIZERS—CROP 1920.

	Over 96 Brix	Over 97 Brix	Over 98 Brix	Over 99 Brix
Per cent of total......	10	35	40	15
A. P. Mol.	30.5	30.3	29.5	28.8

FILTER PRESS WORK.

The work at this station at Makaweli, compared with Lahaina, offers a remarkable contrast. It must be mentioned here that the station at Lahaina was composed of the latest type of filter presses, and better results were naturally to be expected, but I feel convinced that the difficulties experienced here were due mainly to the quality of the settlings.

During the season of 1917 Lahaina had only four presses of 800 square feet filtering surface each. There was at no time any difficulty in getting away with the settlings, or in keeping up the low sugar content of 1% in the cake. Mr. Walker in his last year's report on Standardization says:

"I know of no reason why we need so much less filter area at Pioneer. Possibly it is in the nature of the juice."

I will admit that the presses here are not of the latest type, which will account for some of the difficulties in sweetening off satisfactorily. However, as the sugar content varied between 1.5 and 5%, the cause must be looked for, partly in the nature of the material to be filtered, and partly in the equipment itself. In order to reduce the sugar content, four resettling tanks were put up in the early part of the season. A few previous experiments showed that this resettling could be accomplished in good time, but after actually working the process for a few weeks, with varying applications of heat and lime, we found that some scums would resettle nicely, others poorly, and most of them not at all, and we discontinued this resettling, as the sugar content of the press cake remained equally high.

At Lahaina I believed that the amount of cush-cush in the mixed juice was responsible for the good filtration and the easy extraction of sugar. We have tried larger perforations in the juice screens, and even added cush-cush to the settlings here, with no result. Equally of no advantage were the experiments with a phosphoric acid clarifier, or with a complete change in the filter cloth material. On some occasions the settlings would filter nicely, and fill the frames in good time, but after about half an hour of water pressure the presses refused to let any water through. The presses were filled, as at Lahaina, from a supply tank 25 feet overhead, and sweet water was forced through for about one hour under a pressure of 40 pounds, then clean water for two hours under a pressure of 50 pounds, the total time for sweetening off being three hours as against one and a half hours at Lahaina. Our average sugar in the press cake this year is 3.82%, while Lahaina will probably be below 1%.

These differences at the two factories open an interesting problem. The mixed juice is divided into clarified juice and settlings; the juice evaporated to syrup, and massecuite works more easily at Makaweli than at Lahaina, particularly in regard to low grades, while the settlings collected in the filter presses are far more refractory and difficult. If a research could be made into the entire composition of the whole juices and separated products of two such places as above, some interesting light might be thrown on some of the uncertain phases of sugar manufacture.

From Mr. J. W. Donald, Kekaha Sugar Co.:

BOILING—GENERAL METHODS.

The method of systematically boiling mixed strikes of syrup and molasses, developed in Java and referred to a few years ago as "The Java Process," had for its original aim the production of only one grade of massecuite which would yield shipping sugar and waste molasses. This aim has never been practically attained, even in Java, owing to the high density of the massecuite, the consequent difficulty in handling and purging it, and the excessive amount of washing required. But the modification of it in which two grades of massecuite are produced is in very general use in every sugar-producing country. In this method, the proportions of syrup and molasses in the first strike are so arranged that the massecuite will always have appoximately the same quotient of purity—as also the resulting molasses. No calculations on the pan floor are required. A table is prepared for the use of the sugar boiler showing at a glance the proportions of syrup and molasses (according to the purity of the syrup—the molasses purity being approximately constant) which must be used to obtain a massecuite of the desired quotient.

The causes of fluctuation in the purity of the molasses are frequent changes in the purity of the syrup and variations in the density to which the massecuite is finally brought before striking. This latter difficulty is very slight with skillful pan men, and is, in any case, common to all methods of boiling.

This is a neat, simple and scientific **modus operandi,** and the great advantage it has over the method you outline in your circular is that there is only **one** A massecuite and **one** A molasses. Pan men, centrifugal men, and all others, do not have to change their procedure from one strike to another; they are always handling the same material and can always work the same way. All the molasses storage capacity required is just what is sufficient for one strike of A and one of B.

EVAPORATION—REMOVING SCALE.

Any ordinary incrustation will be dissolved or at least broken down and left as a mere slime by caustic soda without any other agent, mechanical or chemical, particularly where the scale is largely composed of silicates and organic salts of lime and magnesia. The soda solution, however, must be very much stronger than is usually employed, and it must be given time. With solutions of 12.5 to 25% NaOH (1.14 to 1.275 S.G.) a heavy coating will be removed in one to five days from every corner and crevice of the effect, depending on the thickness of the scale. No heat above atmospheric is required.

I am unable to say if still stronger solutions and a boiling temperature would not enable us to get the same result in the time at our disposal between Saturday and Monday.

There are numerous scale solvents on the market under various trade names. Most of these are simply anhydrous carbonate of soda (soda ash) and cannot compare with caustic soda in efficiency. They change the silicates to carbonates, and these latter generally remain as firm a scale as the former, although they can be easily removed by an additional treatment with dilute acids.

From Mr. W. K. Orth, Koloa Sugar Co.:

EFFECT OF TEMPERATURE ON CLARIFICATION.

I found that your theory worked well with sound juices, but with juices coming from cane that had suffered deterioration or decay, the sterilizing effect of heat seems necessary for keeping.

BOILING.

I always try to get the molasses through the house with as little reboiling as possible, which is the essence of the method you describe.

LOW-GRADE WORK.

At the start of the season I boiled to a light string proof, but added sugar dust, kept on boiling up to 100 Brix, as formerly, time of boiling being about 12 hours; 27″ vacuum throughout. Our cane had suffered severely by drought, and on account of the poor stand and labor conditions, we could not be particular about the soundness of the material fed into the mill. The massecuite would rise (swell, not foam) in the crystallizers to a degree never before experienced here. It would rise and stay risen, would not behave in the conventional way when a fillmass rises and slowly goes back again. I kept the juice in turns acid, neutral, and alkaline, at high and low temperature. The results were in each case much the same. The grain was very even and of fair size, but after ten days in the crystallizers and after having been thinned down with water to 95 Brix or less, it would take more than an hour to dry half a machine full. The purity of the massecuite varied from 55 to 58. However, the crystallizers kept over as experiments for 20 days would

dry well in a short time and the purity of the waste molasses would come down as low as 28 apparent. I dropped boiling to such high densities and gradually came to 96.5 Brix. The trouble was not remedied, and I changed my way of boiling.

I boiled to proof, drew in dust, stopped the pan and after due time proceeded in the familiar way. The size of grain was about the same as before, but not as even; temperatures and densities as well as purities were not changed. My previous troubles as to swelling in crystallizers were over, but a new one developed. False grain would frequently come in the crystallizers. I could not boil longer than 12 hours on account of the low purities of our juices and for other reasons, so had to do something to keep ahead of the mill. I knew from experience that this false grain could be prevented forming in the crystallizers by dropping the strike into containers that had previously been heated to the temperature of the pan and then keeping it warm until the supersaturation had worked down below the danger point. But as I had no water-jacketed crystallizers, I tried to get the same results by having about 20 gallons of water in 450 cu. ft. crystallizer when the strike was dropped in. It worked: no more small grain formed, the stuff dried well after ten days, and the purity of the waste molasses was as low as ever. My average for the season is 38.1, but that is no criterion; the quality of our juices is responsible for that high figure. I do not know why most of it should not come down to 36 as it did when I could allow a little more time in the crystallizers. To explain a little more: the massecuite leaving the pan was, say, 97 Brix; six hours after (the water being all absorbed), 96.3; two days later, 96.6. Further water added from the fifth day on until it was dried at 95. It was suggested to me not to boil as stiff or to add something to dilute the mass in the pan. These are not the same as adding the water right after striking. The desugarization should be driven as far as possible in the pan. The water added as I did serves only to prevent a dangerous rise in super-saturation due to the rather sudden cooling. The small amount of water is rapidly taken up, and even if some little sugar is melted, that would, at this early stage, not do anywhere as much harm as the fine grain.

CRYSTALLIZER WORK.

By the statement that desugarization should be driven as far as possible in the pan it is not meant that extremely slow boiling should be resorted to. As long as you boil slowly enough to have first a good foundation to build on, then have the grain grow without false grain forming, the desugarization in the pan is mainly a question of evaporating the water that keeps the sugar in solution. How long that takes and how far you may go depends entirely on local conditions, raw material, pan construction, and the skill of the pan man. To boil slower than is required to do that work is a waste of effort. Besides, I do not believe in subjecting very impure sugar solutions to the dangers of local overheating longer than necessary. Further desugarization is a question of careful temperature reduction, a work that belongs to the crystallizers.

But not only does desugarization take place in the crystallizers, but changes occur in the massecuite as well that have to be considered locally when thinking about crystallizer capacity. These changes are due to the nature of the impurities, that differ much in different places, but are more or less prevalent in the particular locality year after year. I certainly find here that the drying of a massecuite is often much improved by longer standing, even after the maximum desugarization has been reached.

From Mr. J. P. Foster, Maui Agricultural Co.:

I am enclosing a set of card forms which have been used satisfactorily at Paia for some years. They are of good quality cardboard, 5″ high x 8″ long, and fit a standard file. They are used for all routine control work of the laboratory, and, in our opinion, offer many advantages over ordinary record books. I enclose also a field record and a daily report to the manager. For convenience in the following references I am numbering them from 1 to 14 inclusive.

Card No. 1 needs no explanation. It presents for instant examination all the essential cane data required here at Paia. Please note the daily entry of the Java ratio.

Card No. 2 shows the method of correcting averages on products where no direct weights are available. It is grossly inaccurate to take an arithmetical average of the solids and sucrose analyses to represent the average analysis for the week, as, in so doing, the figures for a partial day's grinding of, say, 500 tons may be placed on an equality with those representing two or three times as much material.

In order to minimize this possible error, we make use of two factors derived from the weight of mixed juice. "Factor A" represents tons of solids in mixed juice, and "Factor B" represents tons of sucrose in mixed juice. The per cent solids and per cent sucrose of normal juice are multiplied by "A" and "B" respectively, and the products entered in the appropriate column on the card. At the end of the period, the totals of the last two columns are divided by tons solids and tons sucrose for the corresponding period, as found on Card No. 4, and the results entered in the first two columns as the average solids and average sucrose for the period. We do not claim this to be an absolutely true average, but

CARDS USED FOR LABORATORY ACCOUNTING AT MAUI AGRICULTURAL COMPANY.

CANE GROUND for week ending

	Gross Time	Nett Time	Tons per Hour	Tons Cane	% Suc.	% Fiber	M.J.% Cane	Tons Sucrose
Monday								
Tuesday								
Wednesday								
Thursday								
Friday								
Saturday								
T. & A.								
Previously								
To Date								

NORMAL CANE JUICE for week ending

Crop of	Brix.	Suc.	G. P.	Factor A.	Factor B.	Brix x A.	Suc. x B.	
Monday								

MIXED JUICE for week ending

Tons	G. S.	D. P.	G. P.	Tons G. S.	Total Suc.	Suc. % Cane	Suc.% on Suc.	Pounds Lime

SUGAR MANUFACTURED for week ending

Tons Ex.	Pol.	G. P.	Tons Sucrose	Tons White	D. P.	Tons Sucrose	Total Tons Sucrose

FINAL MOLASSES for week ending

Crop of	Tons	G. S.	D. P.	G. P.	Tons Sucrose	% Glu.	% Ash.	G. S. % Sug.	Tons G. S.

FINAL MOLASSES for week ending Card No. 2

Crop of	True Solids	Tons T. S.	True Purity	Tons Ash	Total Glucose	% Total Sugars	Tons Sugars

Tons FIBER and WATER for week ending

Crop of	Water in Bagasse	Fiber in Bagasse	Water in Mud	Fiber in Cane	Water in Sugar	% Water in Sugar	

RESIDUES for week ending

Tons. Mud	Pol.	Tons Suc.	% Water	Tons Solids	Tons Bagasse	Pol.	% Water	% Fiber	Tons Sucrose

FIELD NO. ....

CROP OF	CROP OF ....
ACRES	
BEGAN CUTTING	
FINISHED CUTTING	
TONS OF CANE	
TONS OF CANE PER ACRE	
TONS OF SUGAR	
TONS OF SUGAR PER ACRE	
CANE RATIO	
VARIETY OF CANE	
FIBER IN CANE	
BRIX	
SUCROSE	
PURITY	
ESTIMATED CANE	
.... ESTIMATE	
ESTIMATED SUGAR	
.... ESTIMATE	
SUGAR.............ESTIMATE TO DATE	

DAILY REPORT TO THE MANAGER

Crop of .... th Week, th Day.

	This Date	*To Date*	*This Date*	*To Date*
Mill Juice				
Sugar				
Cane				
Extraction				
Hours Grinding				
Cane per Hour				
Bagasse Moisture				
Cane Ratio				
Sugar Stored				
" Shipped				
Gals. Fuel Oil				

believe it to be much more accurate than an arithmetical average, and we believe that if the analyses of the intermediate products are worth keeping, they are worth keeping as accurately as possible.

The same method of calculation as shown in Card 2 is followed for individual cards, for first expressed juice; for last expressed juice; clarified juice; and syrup. On all other material, as cane, mixed juice, sugar, molasses, and residues, true averages are obtained from direct weights, the bagasse being referred to the cane weights. It will be noted that most of the cards have a blank column, in which other desirable data may be entered.

The use of Card No. 13, "Daily Report to the Manager," is based upon the belief that the busy manager has neither the time nor the inclination to hunt through voluminous reports in order to obtain the few items which are of daily interest to him. In this card the analysis of mill juice is entered in four groups; for example: 23.58 : 21.96 : 93.10; 21.03 : 18.80 : 89.40; 19.98 : 17.83 : 89.24; 19.89 : 17.49 : 88.02. The first group is the solids, sucrose, and purity of first mill juice for the day; the second group, the same for the crop to date; the third group is the analysis for the corresponding day of the previous year; and the last group shows the average of the previous year at the same date. Under "Sugar" is entered first the tons, then the polarization, and the same with cane. The other items are self-explanatory. This card is placed upon the manager's desk each morning, and after his inspection, is filed in a small card cabinet on his desk. It is probable that such a system, with modifications to suit individual requirements, will be more satisfactory to the managers than the usual form of elaborate report sheet.

The Field Report, Card No. 14, contains all of the essential data to each individual field, and at the right of the card is entered the corresponding figures from the last preceding harvest of the field. The blank space under "Estimated Cane" and "Estimated Sugar" are filled in "Under Estimate" or "Over Estimate," as the case may be. In the last line is entered the crop standing, in total tons over or under the crop estimate to date. The back of the card is standard ruled for the purpose of giving special data, as fertilizing or cultural operations which it is desirable to record. These cards are filed in the same cabinet on the manager's desk in which the daily reports are placed, and a very small space contains the field records for several years, which are of great value to him in making his estimates, and enable him to see at a glance data which might otherwise require considerable search to produce.

From Mr. G. Giacometti, Olaa Sugar Co.:

During the present season the only departure from our former method of boiling is the graining of the low grade with white powdered sugar in proportion to 100 cc. to 1000 cu. ft. massecuite. After working in this way for the entire season we are satisfied that it is an improvement. The grain is certainly more even and when used for seed in boiling commercial grade its influence is still more apparent. For reasons that we do not understand, it seems that sugars boiled in this way are practically free of conglomerate.

Hoping to better exhaust our final molasses we are trying to reduce the size of the grain and raise the density. It looks as if this is the right direction, but it causes such a slowing down in the curing process that it is doubtful that we can go much farther with our equipment or even keep the present standard when the boiling house is pressed.

In regard to false grain, we have been trying to prevent the formation of same in the crystallizers, or, better said, on the way from pan to crystallizers. When the strike is ready to drop it is practically free of false grain, but after a day or so in the crystallizers it is often quite the contrary. We suspect that the massecuite of high density in passing from the pan to the crystallizers is chilled, with consequent effect on the supersaturation. We have been experimenting during the past few weeks with lowering the density just prior to striking the pan. Although too early to form a definite opinion, results so far are very encouraging.

A few hours before opening a crystallizer we dilute the massecuite with a few gallons of cold water. It helps considerably in the centrifugals, and we have never been able to detect any effects on the final molasses.

From Mr. H. D. Beveridge, Onomea Sugar Co.:

1. We have obtained the best clarification of juices at 210° to 220° F., and try to average around that temperature. With a lower temperature we have found a large deposit in pre-evaporator and first cell of evaporator. We have never tried above 220° F., for fear of destruction of sucrose through overheating.

2. We boil out with caustic soda solution at atmospheric pressure and clean out with scrapers and brushes.

No heavy scale formation has been secured for several years.

3. The method described by you has the advantage of starting with fresh molasses every third strike, which is desirable.

Would the three grades of sugars have to be mingled to meet the requirements of the refiners? If so, quite a lot of extra machinery and handling would be necessary to accomplish this.

I am inclined to think the method in vogue at Onomea and most of Brewer's plantations, where we make one grade of sugar of uniform polarization and start with fresh molasses every week, as simpler and more economical on steam consumption than the method described by you.

Another method practiced at Honomu for several years may be of interest. Two pans were started on magma of low-grade sugar and syrup, and finished with syrup and remelt. Massecuite, 82 to 86 apparent purity; sugar, 97.8 to 98.2 polarization; molasses, 66 to 70 apparent purity. One and one-half pans dried off, all this molasses taken on half pan and struck. Massecuite, 78 to 80 apparent purity; sugar, 96.0 to 96.5 polarization; molasses, 52 to 55 apparent purity. This molasses was boiled to crystallizers. The two grades of sugars were marked and kept separate. This method gave with 86 to 88 apparent purity, syrup approximately 70% of sugars of 98 polarization, and 30% of sugar of 96.0 polarization.

4. Onomea method for boiling low-grade strikes is as follows:

Grain started in 250 cu. ft. pan with 50 to 54 apparent purity molasses diluted to 78 Brix, taken to 600 cu. ft. pan and completed, making one strike, and cut or 900 cu. ft. to each crystallizer. Boiled with exhaust steam 2 to 5 pounds pressure at 27″ vacuum, 135° to 140° F. if possible. We make a practice, after the grain is well started, to take into the pan a measured amount of molasses at each charge, increasing this amount slightly as

the pan builds up, and bringing the density of massecuite after each charge of molasses to 94-95 Brix. We seldom have trouble with false grain. Although the crystals will not grow all the same size, we get a fair drying No. 2 sugar, of 81 to 83 polarization or about 86 apparent purity. We drop these strikes to crystallizer at 97 to 98 Brix.

For this kind of boiling one needs ample pan capacity, as the process is naturally slow. Taking three to four hours in the graining and 20 to 24 hours to complete one crystallizer in the striking pan, the whole time consumed for one crystallizer is from 24 to 30 hours.

5. Crystallizer Work. According to experiments made last year at Onomea and substantiated by further experiment this year, crystallization of massecuite is practically complete when the massecuite reaches atmospheric temperature, which at Onomea is from four to six days. After that time only a slight drop was noticed.

We have no data on the effect of water added to massecuite in the crystallizers, but believe it will always increase the purity of the resultant molasses.

We dilute massecuite with warm waste molasses in the magma pump on its journey to the mixer, which we think is a safer form of dilution than with pure water. By this dilution the gravity purity of the resultant molasses is raised 4 degrees. In other words, if it were possible to dry the massecuite without any crystals coming through the screens we could safely get a gravity purity waste molasses of 4 degrees lower than at present. In order to do this our present centrifugal capacity would require being doubled, and even then some of the fine grains would be forced through the screens with heavy molasses and the purity slightly raised.

I think the gain in boiling a 98 Brix massecuite and diluting to 95 Brix for purging purposes, over boiling massecuite to 95 Brix and purging without dilution, is very apparent. The 98 Brix massecuite has already crystallized out more sugar than the 95 Brix massecuite. Without the addition of water the purging qualities of the two massecuites would be nearly the same. With dilution the 98 Brix massecuite can be made to purge much more freely than the 95 Brix massecuite, with as high yield of sugar crystals better dried and of higher purity.

I have no data to bear out my statement, but do not believe it possible to remedy poor pan work in the crystallizers and would expect to see nearly the same difference or 7 degrees difference in the purity of the two molasses at the end of two weeks.

From Mr. R. J. Richmond, Hawi, Hawaii:

CLARIFICATION.

We usually heat our juices to 214° F. If we use low heat, say 180° to 200°, the clarification is not as good. Continuous settlers are used, and juice is left over night, as we work in the daytime only. This juice is heated to 180° to 200°. In the morning on starting up, it sometimes shows a loss of 2 to 5 degrees purity. On occasions when we have left clarified juice from Saturday till Monday it has lost considerably in purity, though preserved with formalin in proportions of 1:500, and alkaline to litmus paper. This may result from the juice being in contact with the settlings, and also the excelsior in the settlers, containing the solid matter caught during the week's run. For this reason I always endeavor to boil off on Saturday night.

SCALE.

For the cleaning of the effects, we use only soured molasses with an occasional boiling out with muriatic acid about once a month, cleaning out on Sundays with scrapers of brass wire fixed round rubber rings on wooden rods. If the scale is hard we occasionally have to use iron scrapers. I have used soda ash in mixed juice, half a pound to a thousand gallons, with good effect in softening this scale, but gave it up on account of cost.

SUGAR BOILING.

The system of sugar boiling used at Pioneer looks rather good to me, but would have to be tried out under varying conditions of different mills. In our system of boiling, I have noted that number one massecuites dried hot give a lighter sugar than when held in crystallizer for 24 to 48 hours.

From Mr. R. C. Pitcairn:

LOW-GRADE BOILING.

Here at the Wailuku Sugar Company this past season, all low-grade pans were started on fine sugar dust obtained from the Honolulu Plantation Company. One pound of fine sugar dust (taken into the footing of the molasses at proof point) was used for every 1000 cu. ft of finished low-grade product. This sugar simply acted as a stimulant to the

saturation, making the formation of the grain more nearly simultaneous; the resultant sugar, therefore, more nearly of a size and easier purged, thereby giving us a better seed sugar for our No. 1 pans. In our work we built up one 700 cu. ft. pan, using 2 pounds of the dust, this pan then being used as the nucleus for three pans that were built from it by cutting. There was only No. 1 molasses used in the above work.

FALSE GRAIN.

This is misnamed, and should be called a subsequent grain, as from my experience it is simply a new grain that has formed at the later stage of the crystallization of the body of sugar. The common causes are too small a number of original grain, or an expansion of the massecuite due to heat, water, or an overfeed of molasses separating the already present grain to such an extent that room is allowed for this new formation to take place. Due to the incomplete time for its growth to occur and lack of material to grow on, it is distinctly smaller than the original grain and may even pass through the centrifugal screen, or if present in great multitude, be thrown by the centrifugal force against the screen holes, tending to plug the same.

PREVENTION OF SO-CALLED FALSE GRAIN.

First there must be sufficient grain formed; then careful pan work regarding the feed of molasses and water, good circulation, and good control of the pan temperature, especially in the later stages, and dropping the pan on a cooling temperature, as contraction and not expansion of the massecuite must occur.

This danger can also be to a great extent eliminated by carrying the pan to a high density at all times, particularly before dropping. An ordinary cause of false grain is this: the sugar boiler drops a pan at, say, 95 to 96 Brix, often running the washings into the same crystallizer, expanding the massecuite, giving room for the growth of the grain. This can be stopped by either cutting out the washing or by keeping the massecuite hot in a water-jacketed crystallizer for a few hours before starting to cool the massecuite.

EFFECT OF ADDING WATER TO MASSECUITE ON RESULTANT PURITY OF MOLASSES.

My experimental work this spring has led me to think that it is possible to add water to massecuite under certain conditions with beneficial results.

The conditions are these: On a heavily-boiled massecuite it is possible to add a limited amount of water slowly. While the massecuite is in motion, cooling and contracting to a certain point of saturation will not give a higher resultant molasses than when allowed to cool naturally without the addition of water to the massecuite. The saturation in my work is between 95 and 96 Brix. After the contraction of the massecuite has stopped and the minimum temperature reached for a certain point of saturation, the addition of water raises the resultant molasses purity.

REGARDING COMPLETE CRYSTALLIZATION.

Outside of the time limit at our disposal and tremendous equipment required, complete crystallization is not practical. There is a great probability of small flower grain forming between the original grains after the original grain formed in boiling has grown to a sufficient size. This occurs even while in motion, and because there is not a sufficiently rich mother liquor to develop larger crystals. These flower grain crystals in reality retard purging of the original grain and will go through screen holes used at present.

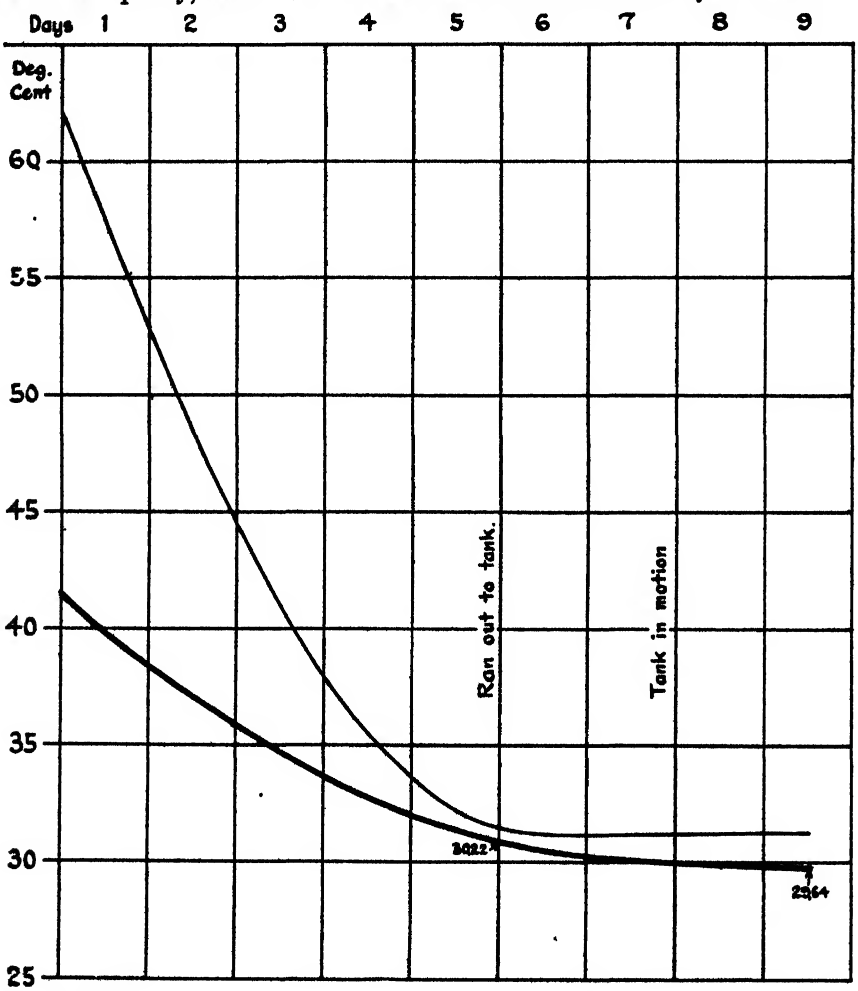
The advantage obtained by boiling to 99 Brix in place of 95 is that it exhausts the mother liquor in the pan and deposits that great portion of the sucrose on the already formed grain, leaving less inter-granular sucrose to be deposited by the contraction that takes place in cooling, cutting out the possibility of false grain and materially shortening the time of economical recovery.

In regard to the advantage of slow boiling of low-grade massecuite, it is mainly due to the better control it gives the pan man and his ability under these circumstances to keep the massecuite well together, and obliterates the dangers that arise from a too rapid feed of molasses and water. Outside of this I can find no advantage but the time element of crystallization in motion, and given two massecuites of the same final Brix purity and number of grains and same size, one taking 24 hours and the other five hours. I believe the molasses in both will finally reach the same point under the same system of temperature control in the crystallizers.

One disadvantage of slow boiling that was brought to my attention this year is the tendency of the longer-boiled pans to show a greater loss of purity in the pans. The time element in regard to low-grade molasses results was brought out rather strikingly—a record of 43 consecutive pans. During five days in the crystallizers the drop in purity of the molasses was 22 points (from 52.22 to 30.22 apparent purity); they then averaged three

days in the outside tanks in slow gravity motion, dropping to 29.64 apparent purity, showing only 0.58 of 1% gained here. It was dropped from pans (average time of boiling 9½ hours) into hot-jacketed crystallizers. A few hours later cold water was turned on the jacket and approximately 1% of water (30° to 35° C.) was fed slowly to the massecuite while it was cooling rapidly. The temperature of the massecuite at the end of the fifth day was 30° to 32° C., or as low as my equipment would give me, at which time I believe I had reached the economical extraction point in my molasses.

The Brix of the original massecuite averaged 97.20. This ultimate drop could have been further lowered by starting with a lower initial purity massecuite. This point of purity of the massecuite and Brix are mainly dependent on the equipment at disposal, down to a certain purity, where the non-sucrose element hinders crystallization.



Massecuite.
Brix 97.20.
Pol. 96.
Purity 52.45.
Cooling water on.
Cooling water off.
Water added (approximately 1% by volume).
Composite of 43 consecutive crystallizers, June 1-25, 1920.
The three days in tank showed drop of 0.57.

(I would like to suggest that a series of experiments be undertaken to establish within reasonable bounds approximately how far down in actual operation we can carry our initial purity and still get a well-building grain within a reasonable working time on massecuite neutral to litmus.)

PURGING LOW-GRADE MASSECUITE.

During the past season at Wailuku and part of the season at Puunene, the stripping arrangements for handling low-grade massecuite were used with beneficial results, shorten-

ing the time of purging 13 to 15% at Puunene and approximately 15 to 20% at Wailuku. Apparently the main reason for these benefits was the manner of applying the heat before the massecuite went into the centrifugals and the resultant change in viscosity of the massecuite, as apparently after it had contracted to give off a low resultant molasses every degree it is expanded before centrifugalizing (if this can be done without injury to the grain) the benefit is very great. This stripping arrangement is merely a simple mechanical means of applying heat in limited quantities under satisfactory control.

Outside of the time limit at our disposal and tremendous equipment required, complete crystallization is not practical. There is a great probability of small flower grain forming between the original grains after the original grain formed in boiling has grown to a sufficient size. This occurs even while in motion and because there is not a sufficiently rich mother liquor to develop larger crystals. These flower grain crystals in reality retard purging of the original grain and will go through screen holes used at present.

AVERAGE RESULTS OF FORTY-THREE CONSECUTIVE LOW-GRADE PANS BOILED AT WAILUKU SUGAR COMPANY, JUNE 1ST TO JUNE 25TH, 1920, INCLUSIVE.

Average hours boiling	9.5
Average temperature of pan, degrees Fahr.	147.5
Average vacuum	26.8
Average Brix into crystallizers — 97.20 out of cryst.	95.91
Average polarization into crystallizers— 50.98 out of cryst.	50.08
Average purity (a) crystallizers — 52.45 out of cryst.	52.22
Average purity (a) hot from massecuite after boiling	40.50
Average purity (a) cold at end of 5.7 days going out to tanks	30.22
Average purity (a) cold at end of 9.0 days coming into house	29.65
Massecuite in slow motion from tank to tank.	
Drop in purity of molasses, 5.7 days	22.00
Drop in purity of molasses, 9.0 days	22.58

The crystallizers used in above work were the circular water-jacketed type. Hot water was on the jacket at the time of dropping pan to keep out false grain forming, which it did. A few hours after dropping pan, cold water was turned on the jacket and the temperature of crystallized massecuite was forced down as rapidly as possible. The above results show the great benefit of the water-jacketed type of crystallizers over the tank system, and that the cooling factor, to arrive at a commercial exhaustion of the molasses, is indispensable when a boiling house is limited by time in its complete cycle of manufacture.

From Mr. F. H. Hadfield, Hilo Sugar Co.:

CLARIFICATION.

We try to keep our juice running through the heaters at about boiling point, as too high a temperature tends to form salts of organic acids, which are dark colored and easily decomposed, forming acid substances which eventually cause inversion. Too low a temperature gives an imperfect, cloudy clarification and with lime does not precipitate the gummy matters, causing suspended matters in the first cells and scale in the last cells of the evaporators.

EVAPORATORS.

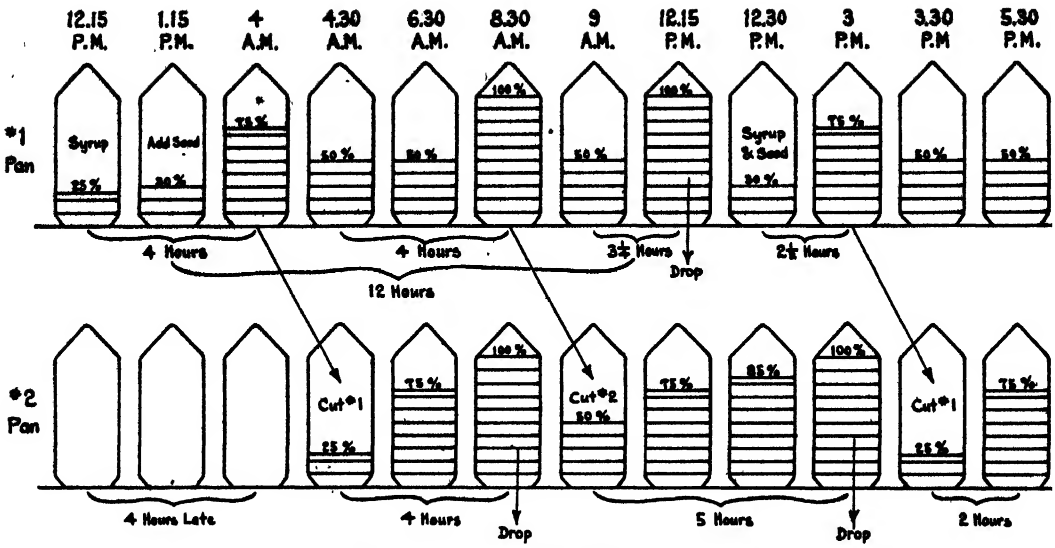
All cells are boiled from four to six hours under atmospheric pressure. In the last cell we use caustic soda, and in the others muriatic acid, as the caustic soda loosens the scale and the acid dissolves any suspended matters deposited through imperfect clarification. Though incrustation in evaporator tubes is unavoidable, it is our endeavor to carry as near neutral a juice as possible, thus decreasing the natural tendencies of either an acid or an alkaline juice of dissolving lime salts and causing scale in the evaporators.

BOILING.

General Methods, No. 1 Massecuite.

Begin No. 1 pan with syrup and boil to string-proof about 25% of pan, then take in seed, building up to 75%. First cut down to 50% of pan, building up to 100%; second, cut down to 50% of pan, building up to 100%, finishing off with molasses and dropping, taking 12 hours.

Begin No. 2 pan by taking first cut from No. 1 pan of 25%; build up to 100%; finish off with molasses and drop. Then take in second cut of 50% from No. 1 pan, finishing off with molasses, and drop.



Sugar boiling at Hilo Sugar Company.

The above is just a rough idea of time and per cent in pans and the nearest approach we have of arriving at an even grain in our No. 1 sugar.

General Methods, No. 2 Massecuite.

Take in 25% syrup of 86-87 purity and molasses of 50 purity, and boil to grain, adding about 5 pounds of carbonate of soda. Build up slowly till 90% of pan, and drop at about 95-96 Brix.

FALSE GRAIN—CAUSES AND PREVENTION.

1. Sudden agitation of magma.
2. If the mother liquid in which the crystals float becomes as high in purity as it was before graining.
3. Forcing circulation at the latter part of the boiling.
4. Charging pan with syrup or molasses of a lower temperature than the massecuite in the pan.
5. Keep the massecuite lower in vacuum during boiling than at the beginning of strike.
6. Steam the molasses before taking into the pan, dissolving any small grain that may be there.

CRYSTALLIZATION.

1. Experiments lead us to conclude that complete crystallization may take about 8 days.
2. A warm temperature is more conducive. Water-jacketed crystallizers would be preferred, as they continue the process of boiling in the pan both with regard to temperature and circulation.
3. The adding of water is unsuccessful, the purity always increasing.
4. It is possible to add water, however, without raising the purity, provided the crystals have been boiled hard, but the process requires skilled attention both during the night and day.
5. Boiling to 99° Brix and diluting with water is advantageous. I have always preferred waste molasses as a dilutant rather than water, as an even temperature is easily kept and requires little attention.
6. It is mixed by a scroll just before entering the mixer.
7. Long and slow boiling gives, usually, hard and large grain, with a well-exhausted final molasses.
8. The massecuite boiled for 24 hours will give a much lower final molasses than when boiled for five hours.

Taking up the individual topics suggested:

CLARIFICATION.

Three places which have tried heating juices to a lower temperature report that the clarification is not as good as at 212°. None of the others commented

on this point. Our experience this year has been that just as clear juices can be obtained at 180° as at 212°, but that as a rule a considerably longer time of settling is required at the lower temperature. We ran through the first four or five weeks at 180°, but as the season advanced and the mill speeded up we had to increase our temperature to 190°, 200°, and finally 210°, always dropping down Saturday night to 180°. We are putting in an additional settling tank for the coming season, which should let us work at a lower temperature again. It may be, too, that the slower settling and greater capacity required at 180° will offset the advantage of less deterioration at this temperature. Our results on juice deterioration this year have been referred to the special committee on this topic.

Evaporation.

Nothing new has been reported under this heading. When the representatives of Crockett Refinery were down here last year, mention was made of a chemical method of cleaning scale from evaporator tubes, using very strong carbonate of soda, followed by muriatic acid. Their method in detail is as follows:

PROCEDURE OF BOILING OUT EVAPORATORS.

(As practiced by California and Hawaiian Sugar Refining Co., Crockett, Cal.)

After all sweetwater is rinsed out of the evaporators, sufficient 20% soda ash solution is pumped into them to just cover the tubes. This is then boiled continuously for 14 hours, making up the loss by evaporation with fresh water. A vacuum of about 10 to 15 inches is maintained in the first body and about 24 inches in the last, no special note being taken of the temperature.

After the fourteen hours the soda is run back to the soda tanks and the bodies are rinsed out, the rinsings also being run to the soda tanks. After rinsing, the evaporators are filled with water to the height of the tubes and boiled for 30 minutes. This removes any soda that has penetrated the scale and makes for economy of acid. This water is run to the sewer, the bodies being again rinsed.

The bodies are then filled with water and sufficient muriatic acid is drawn into the bodies to produce an acidity of 0.3% HCl. This acidity is maintained throughout the boiling period, by fresh additions of acid if necessary. The acid boiling lasts four hours, after which the evaporators are thoroughly washed out. They are generally found to be quite clean after this treatment.

It is a little hard to estimate the quantity of soda actually consumed in this operation. There is some chemical loss, which is probably small. There is also an entrainment loss which can be kept small, but must be watched, as the soda solution foams considerably. Finally there is a mechanical loss in the soda that is washed to the sewer. The sum of these should not exceed 4% of the total used, but will often run much higher if not carefully watched.

The amount of acid required varies with the different bodies, in our case from about 2 carboys (117 pounds each) in the first body to about 12 carboys in the last. The total for the five bodies, each holding about 2000 gallons of water, averages about 30 carboys.

The evaporators at Crockett are of the Wellner Jellinek type, each cell containing 3027 sq. ft. heating surface and requiring about 2200 gallons of liquid to cover the tubes. The chief drawback to the use of this process in Hawaii lies in the amount of soda ash and acid required. Our Standard evaporators as a rule have a much larger ratio of volume to heating surface and would need proportionately more liquid to cover the tubes. 0.3% HCl means about 1 gallon of commercial muriatic acid per hundred gallons of water to start with. This strength of boiling acid attacks iron perceptibly, and a much weaker acidity will not dissolve the scale. At Crockett thus far they have not been able to detect any harmful effects from the acid used, and there has resulted a large saving in labor over the old method of boiling with soda and scraping.

We tried this method at Pioneer during the last month of the grinding season, using about a 15% soda ash solution and in the subsequent acid boiling adding acid to maintain a decided acid reaction to litmus, without trying to control by titration. While the tubes of the Lillies were not perfectly cleaned, the evaporators seemed to work as well as when scraped by hand, and we saved a good deal of labor at the high bonus rate then prevailing. A very important part of the procedure is a thorough boiling out with water between the soda and the acid treatment; a mere rinsing leaves a large amount of soda adhering to the scale.

I have made a good many experiments lately on small sections of scaled tubes, hoping to improve on this process, but without entire success, though the indications are that, with the kind of scale we have here, caustic soda is much more efficient than the carbonate. It removes more scale by itself and requires less acid in the subsequent treatment. As Mr. Donald points out, a very strong caustic soda solution will eventually remove all scale without any acid treatment. I have cleaned small sections of fourth body tubes fairly well by boiling for half an hour in a 50% by weight solution of caustic soda. The cost of such a solution in sufficient volume to cover all our tubes would perhaps be too great, though possibly by working at a very low level it might be made profitable. Another scheme which seems possible is to spray the tubes with a little 50% soda solution, then turn on steam in the calandria, thus concentrating the adhering soda in place. A method which has worked very well on a small scale and which we intend to try out next season, is to boil for about an hour at atmospheric pressure with ten per cent caustic soda, drain off soda to a storage tank, and, without rinsing, turn on steam in the calandria for half an hour. This concentrates the soda left in the scale and cracks off most of the scale, so that the amount of acid required for the final cleaning should be much lessened, provided a thorough boiling with water is given before the acid treatment.

Boiling—General Methods.

The proposal of a standard method for sugar boiling did not arouse as many objections as I had hoped. The choice of methods appears to be narrowed down to two: (1) the method proposed and (2) the one in more general use in Hawaii, where only one purity of first massecuite is made, taking back sufficient molasses into each strike to lower its purity to about 76 to 78. According to published reports this latter method is no longer used to any great extent in any other cane sugar country. It has the advantage of apparent simplicity, as only one grade of first massecuite is made, and of uniformity for the same reason. On the other hand, more molasses is kept in circulation, and since the average purity of the first massecuite is lower than where it is reduced in three stages, the average yield of sugar per strike is lower, which necesarily means more strikes, more pan capacity and more steam for a given weight of sugar produced.

The objection to the first method is that three grades of sugar are made. The average variation in this respect is shown by the following figures from Pioneer:

AVERAGE ANALYSES WHILE MAKING 96° SUGAR, DECEMBER 20, 1919, TO JANUARY 19, 1920.

Purity syrup: average daily, 85.9; highest, 87.8; lowest, 82.7. Remelt, 75.9. Cuts from Pan 2, Brix 87.3, purity 85.3.

	Massecuite			
	Brix	Purity	Pol. Sugar	Purity Molasses
1a	93.0	86.1	97.5	66.0
1b	94.6	78.7	95.1	56.2
1c	95.6	74.5	94.8	52.0

AVERAGE ANALYSES WHILE MAKING 97° SUGAR, JANUARY 19, 1920, TO APRIL 19, 1920.

Seed, 76.5; remelt, 74.0. Syrup: average, 87.1; high, 89.3; low, 84.9. Cuts from Pan 2, 86.0.

	Massecuite			
	Brix	Purity	Pol. Sugar	Purity Molasses
1a	93.4	85.9	97.6	66.8
1b	94.8	78.9	96.9	57.4
1c	95.7	74.7	96.1	53.5

The variation in polarization is greatest when making 96° sugars. It can easily be "smoothed out" if necessary by "painting" the 1A strikes with 1c molasses to reduce their polarization, and washing up the 1c strikes correspondingly, as was done here in 1919 and in 1920 for part of the season. An average of 32 strikes shows the change effected:

	Massecuite			
	Brix	Purity	Pol. Sugar	Purity Molasses
1a	93.5	85.0	96.8	65.6
1b	94.7	77.7	95.7	56.5
1c	95.6	74.1	95.4	53.3

This point was discussed with the technical men from Crockett, who said they had no objections to the method from a refinery standpoint, as the grain was the same in each strike, and they could see no particular use in reducing the variation as done in the last example. The old objection to mixed sugars was on account of difference in grain, where small-grained sugars made from molasses were washed up to polarization and mixed with larger-grained first sugars.

Another objection to Method 1 suggested by Mr. Donald is the necessity for separate storage tanks for the different grades of molasses. In the modification

used here this objection is done away with, as all the molasses from 1A is taken back into 1B, all from 1B is taken into 1C, and all from 1C is boiled for the crystallizers, so the only storage required is one set of tanks for the molasses from a 1A or 1B strike and another for that which is to be boiled for low grade. It was partially for this reason that the modification was made. No molasses is left over waiting for the proper strike to fit into, and none is taken back into the 1A strikes.

Mr. Fries, who, I believe, introduced the 3-massecuite method at Lahaina, objects to the modification of taking back all the molasses on the ground that with low-purity juices the 1C molasses may result too low for good low-grade work. We get around this difficulty by omitting the 1C strike altogether in such a case. An arbitrary limit of, say, 55 purity is set. If the 1B molasses turns out 56 it is reboiled in the next (1C) strike and there reduced to about 51 or 52. If the 1B molasses runs lower than 55 it goes to the low-grade pan without further boiling and the next No. 1 strike is made from straight syrup. I do not know that there is much choice between the two methods, but the modification seemed a little simpler in that it avoided all calculations or tables and that no first molasses was kept in circulation. Theoretically it seems better to have a constant purity molasses for low-grade boiling, but a difference of four or five points did not seem to make much difference in our results, as long as the minimum was not below 50.

Von Stietz* describes a method used in a Java factory where three boilings at 85-90, 80, and 70 purity for first massecuite and one at 60 purity for second massecuite were made. This is very similar to our Method 1. It was subsequently discarded because too much molasses was kept in circulation! The method finally adopted was as follows:

Strike No. 1, made from syrup of from 85 to 90 purity, yielding raw sugar of 98.4 to 98.8 polarization and molasses of 70-75 purity.

Strike No. 2, grained from No. 1 molasses and built up on same, yielding a No. 2 sugar which is used for seed in the No. 1 strikes and a molasses of 45-50 purity.

Strike No. 3, made from a cut of No. 2 and built up with 45-50 purity molasses to a massecuite of 60 purity for the crystallizer, yielding a low-grade sugar which is remelted, and a final molasses.

A somewhat similar method was, I think, used at one time at Ewa.

Were we permitted to make a 98 polarization sugar I would consider such a method the ideal one, as it minimizes the amount of molasses returned and, graining in a purer medium, furnishes a better and larger seed grain for the No. 1 sugars, but it would not be advisable to consider this method under existing conditions in Hawaii on account of the difficulty in keeping the sugar down to 97 polarization.

Boiling—Low Grade.

The feature of the year is the very general adoption of the use of powdered sugar for forming grain. Those who have tried it out almost without excep-

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* Louisiana Planter, 1920, p. 92.

tion are in favor of it. The method is used at Crockett Refinery for graining all their white sugar as well as their low-grade strikes. About a quart of powdered sugar is used for a 1700 cu. ft. strike. They do not consider that the sugar introduced is really the grain on which the strike is built, but believe the sudden shock, together with the spreading of a few crystals through an already supersaturated solution, causes crystallization to take place. The amount of sugar taken in for shock seeding or the size of grain used does not make much difference, the important point being the density of the syrup at the time it is seeded.

At the Spreckels beet sugar factory they have worked out a very rapid method for graining first sugars. A small single-effect evaporator furnishing vapor to the heaters concentrates a portion of the syrup to about 80 Brix. This is kept in separate storage tanks. When a pan is started up they draw in a charge of this practically saturated syrup, turn on the steam, give it a shot of white sugar and go on boiling; the grain appears immediately.

We have been trying the powdered sugar graining method at Pioneer off and on during the past season, the majority of our low-grade strikes being thus grained. Our sugar boilers are not enthusiastic over it, and are not at all sure that the grain comes any quicker or evener with than without its use. We originally used C. & H. powdered sugar, made up of irregular crystals varying from 0.01 to 0.10 mm. in diameter, averaging about 0.05. Our finished No. 2 massecuite averages about 0.3 mm. diameter of crystals and a total weight of about 10 tons crystals. If the powdered sugar alone supplied the seed for one strike, the crystals would have to grow to only six times their original diameter or 216 times their original weight, so the weight required for seeding would be $\frac{20,000}{216} = 92$ pounds per strike. We next tried some sugar dust, which has a very much finer grain, averaging possibly 0.01 mm. in diameter. Theoretically, less than a pound of this should furnish enough grain for a strike. Results from this were no better and no worse than with the coarser-grained sugar.

A possible explanation of our inability to detect any improvement from the use of powdered sugar is that we have already been "shock seeding" without knowing it. The majority of our strikes are grained by boiling to proof and dropping into an insulated tank. As there is always a good deal of old grain left in the bottom of the tank, this, together with the agitation brought about by dropping, may in itself be enough to induce crystallization. On the other hand, many of our strikes were grained in the pan, with and without powdered sugar, and we have never been able to detect any consistent difference in results. We grain by boiling to proof and letting stand. Grain first appears in about half an hour, but takes about two hours standing to grow big enough to start boiling. The amount of grain produced varies with the Brix, purity and *stickiness* of the boiled-down molasses, and the variations from these causes are greater than from the presence or absence of powdered sugar.

We expect to continue its use next season and may know more about it after another year's trial.

False Grain.

Most of us are apt to blame the crystallizers for false grain in low-grade massecuites. Last year, in an attempt to remedy this evil, we insulated and covered the two crystallizers nearest the pan, dropping molasses strikes directly into these alternately and pumping the massecuite out and into the ordinary crystallizers after 12 to 24 hours. The insulation was fairly efficient; massecuite dropped in temperature only four or five degrees Centigrade in the first 24 hours, against ten to twelve degrees in the open crystallizers. Considerable crystallization took place during this time, as is shown by the average of 24 strikes:

	Brix.	Purity.
Massecuite	97.0	53.9
Molasses, separated at once	95.3	44.8
Molasses, separated after 14 hours	95.3	40.5

The grain was quite regular, and practically no very small grain was seen in any of the strikes. The molasses was rather more viscous than usual and harder to separate in spite of the good grain. This was while we were running the mill slowly. As the mill speeded up and we had less time for boiling, the grain got worse and soon it was no better than in previous years. We then tried running every other strike direct to the regular crystallizers. For several weeks we examined almost every strike with a microscope, but were unable to detect any difference in size or appearance of grain between massecuites which had cooled directly in open crystallizer and those that had been kept warm for half a day. A record is kept of the drying time and the apparent purity of molasses from each crystallizer. The average time of drying (700 cu. ft. massecuite dried in twenty-four 30″ and two 40″ machines), and the average apparent purity of molasses from the "insulated" and the "direct" massecuites is given below. During part of this time we were using steam outside the centrifugal baskets to help drying. Massecuites dried cold and those dried with steam are averaged separately.

	Steam		No Steam	
	Insulated	Direct	Insulated	Direct
Number of crystallizers	14	14	8	11
Hours per crystallizer	11.26	11.36	23.81	20.70
Purity molasses	34.96	34.35	32.16	32.07

As there was no benefit shown by the insulated crystallizers we stopped using them. We have made a large number of microscopic examinations of low-grade massecuites, following them up from day to day, and never, when the ordinary method of boiling was used, have we noticed small grain appear which was not present when the crystallizer was first filled.

In an attempt to find out the influence of rapid cooling we took samples of massecuite from the flume at the time of dropping a strike and from the still warm

crystallizer at 24-hour intervals, put them in mason jars tied to the large gear outside of the crystallizer, thus cooling them down to factory temperature in a few hours, and compared them under the microscope with the massecuite cooling normally in the crystallizer. The sample taken on first dropping the strike developed a large number of new crystals of about 0.01 mm. diameter. Samples taken from the crystallizer after 24 hours or more showed no traces of this small grain. We still have these samples, and even after several months' standing no difference can be seen between those cooled rapidly after 24 hours and one taken from the crystallizer after 13 days. We did not carry the experiment further to determine the exact time limit of safety before rapid cooling, but have proved that with our massecuites at least it is less than 24 hours.

Mr. Pitcairn has further demonstrated this at Wailuku. By turning cold water on his jacketed crystallizers after the first day he has been able to cool down to 30° C. in four to five days, saving considerable time in crystallization. (Our 700 cu. ft. open crystallizers take from 6 to 9 days to cool down to 30°.) His results show that the drop in purity of molasses follows the temperature line very closely, and he has not been troubled with any false grain due to faster cooling.

After a heavy massecuite has been dropped, the flume, unless scraped clean, will continue to drain slowly for 24 hours or more. An examination of these drippings shows them to be full of fine grain. Of course, their proportion to the total massecuite is very small. The remedy is obvious, but not always easy to apply.

Mr. Orth's scheme of adding a few gallons of water to a crystallizer just before filling is novel and worth trying.

Size of Grain.

If the percentage of grain less than 0.1 mm. long is kept low we have not found an irregular grain to be a disadvantage in drying. I believe a massecuite made up of half 0.2 mm. and half 0.5 mm. grains will dry better than one all 0.2 mm. Towards the end of the season we tried to emulate our Cuban friends and boiled one large-grained strike on a cut from No. 1 massecuite. The cut was 74.9 purity, the molasses boiled in 55, and the finished strike 96.0 Brix and 60.9 purity. In spite of careful work and slow (12½ hours) boiling, false grain came in at different stages, mostly toward the end. The finished strike consisted of the original grain, 1.5 to 0.8 mm. long, secondary grain which had come in early and grown to 0.2 to 0.4 mm., and a large amount of "false" grain ranging from 0.01 to 0.05 mm. The boys found it almost impossible to "separate" this massecuite, as the fine grain plugged up the screen of the separator. I predicted that it either would not dry at all or might partially dry with a layer of molasses on the outside.

After a week we tried four buckets full in a 30″ machine. To the surprise of everyone it dried fairly well in 15 minutes and perfectly in 30 minutes, yielding a far better sugar than we ever get from our low-grade massecuites. The molasses run-off contained considerable fine grain and had an apparent purity of 32, which is lower than our average.

An examination of the dried sugar under a low-power microscope solved the mystery of why false grain didn't prevent a good drying. Adhering to the surface of nearly every large crystal were seen numerous very small ones. The

large grain had acted as an aid to filtration by increasing the "screening area." It was apparent that had the grain been made more even by removing the very large crystals, drying would have been much more difficult.

It is barely possible that by following up this idea an improvement in our low-grade work might be developed. The trouble with our present method is that to get crystal surface enough for the proper exhaustion of low-grade massecuites they have to be made of very small grain. This means a slow-drying massecuite, a comparatively low polarizing second sugar and more adhering molasses which is necessarily returned to process. Could a mixed grain be developed in some way, which would have sufficient small grain for good crystallization and sufficient large for better drying?

Experimental Strikes.

On the few occasions last year when the boiling house was not working to full capacity we tried some experimental strikes, boiling by entirely unorthodox methods just to see what would happen. Most of them turned out unsaitsfactorily, but they may be worth recording if for nothing more than to save someone else the trouble of doing the same thing.

No. 438-8. Thirteen tons molasses of 54.8 purity boiled blank in 45 minutes, about a quart of powdered sugar added and dropped to a crystallizer. Grain appeared in 1½ hours, and in two hours was a very good square grain from 0.05 to 0.10 mm. long. At this time a second blank strike consisting of 22 tons molasses of 50.7 purity boiled in 1 hour 10 minutes was dropped on top of the first. Seven hours after dropping the second portion, the original grain had grown to 0.10 to 0.15 mm., but a large number of secondary grains of 0.05 mm. had come in. Ten hours later the grain had not grown any more, the mass foamed up badly, and the temperature rose to 66° C. An ordinary strike would have been about 57° C. at this stage. The mixed strike was 97.8 Brix and 52.1 purity. After standing 39 days it dried fairly well (on dilution) and gave a molasses of 90.6 Brix and 32.9 apparent purity.

No. 583-17. Grain made similar to the above, from 2 tons remelt and 12 tons 51.4 purity molasses boiled blank and dropped to a crystallizer. Eight hours later a second lot of 24 tons 51.0 molasses dropped on this. Complete strike was 99 Brix and 51.0 purity. The original grain finally grew to about 0.2 mm., but a large amount of small grain of 0.02 to 0.05 mm. also appeared. This strike was very hard to dry.

No. 584-2. Twenty-five tons of 51.4 purity molasses were boiled blank in 1 hour 15 minutes and dropped into a crystallizer containing about 10 tons of old massecuite. Much false grain appeared. This is about the worst I have seen.

No. 582-16. Grain was made in the pan from 12 tons 52.8 purity molasses. After grain stood in the pan for 6 hours, 22 tons No. 2 molasses of 35.5 purity were boiled slowly, taking 7 hours to boil. Finished strike was 99 Brix, 40.7 purity, with fairly good grain from 0.1 to 0.3 mm.; very little smaller.

No. 579-3. Twenty-five tons No. 2 molasses of 85.8 Brix and 33.4 purity were boiled blank to 100.2 Brix in 1 hour 40 minutes and dropped into a crystallizer containing about 11 tons of 33 days old massecuite of 96.6 Brix and 55.8 purity. This molasses was boiled so heavy it took 5 hours to discharge from the pan. Mixed strike was 98.4 Brix and 39.1 purity. No secondary grain appeared in this strike. Purity of separated molasses after 2 days was 30.7; in 4 days it had cooled to 36° C. and the separated molasses was 29.7 purity; after 9 days, purity was 27.4; 18 days, 25.9; 31 days, 24.9; 37 days, 24.7; 79 days, 24.6. This is the most promising experiment tried yet; the grain is uniform and fairly large—about 0.4 mm. Given sufficient pan, cooling and centrifugal capacity it might pay to go after a lower purity final molasses by working it in two boilings instead of one. We intend to experiment further along this line.

No. 586-4. The first experiment of boiling "waste" molasses blank turned out so well that we tried one more, with the idea of making it crystallize out on a much larger grain. Thirty tons of molasses of 83.4 Brix and 37.4 purity were boiled to 99 Brix in 2 hours 45 min. and dropped into an empty crystallizer, taking 3½ hours to discharge. Two tons of dry No. 1 sugar were added as the crystallizer filled. No secondary grain appeared at first, but after 24 hours it came in large amount. After three months in the crystallizer the grain has grown very little, the majority being 0.02 to 0.1 mm. Evidently not enough "seed" was used to take up the sugar crystallizing from a 37.5 apparent

purity molasses. Somewhere between the conditions of the last two experiments there may exist a happy medium with enough crystal surface to take up all the sugar that will come out, and still be large grained enough to yield a well-dried sugar.

Time for Complete Crystallization.

This seems to vary in different factories. Tests made at Onomea and at Hilo Sugar Co. indicate that crystallization is practically finished in from four to eight days. At Pioneer we have held over a number of crystallizers and made separations at regular intervals as we did last year, and invariably find a drop in purity of molasses of from one to two points between the fourteenth and the twenty-eighth day. After the first month the drop is very slight, probably less than one point on standing four months longer. The massecuite itself does not drop in purity during one month; we have not yet checked it up for longer periods.

Probably the nature of the impurities in the molasses has a great deal to do with the duration of crystallization. Molasses from around Hilo is generally considered to be easier to reduce to a low purity than that from other places; if the crystallization takes place easier, it is logical to suppose that it will be completed sooner. Another reason for the difference may be that some factories do more of their crystallization in the pan than do others. Due to our small low-grade pan capacity, many of our strikes have to be boiled in less than six hours. The average of 88 separations on hot massecuite leaving the pan last year at Pioneer was:

	Brix.	Apparent Purity.
Massecuite	97.0	54.0
Molasses	95.7	44.3

Some factories are able by long boiling to get the mother liquor in a low-grade strike down to less than 40 apparent purity, which would tend to shorten the time for after-crystallization.

Effect of Adding Water.

We have never been able to add water to a low-grade massecuite (and we have tried every known method), without raising the ultimate purity of its molasses. Unless we accept the now disproven theory that a concentration to a higher than the usual factor Brix does not cause more sugar to crystallize out, it is obvious that reducing this Brix in any way must dissolve sugar. We have, indeed, added water in small amounts to a massecuite which was still cooling, and obtained a continued *drop* in molasses purity, but similar massecuites without the water dropped still lower.

Experimental work on a small scale indicates that it is possible to separate the molasses from a highly-concentrated massecuite, add a small amount of water to it, mix with sugar and separate again with very little if any increase in purity. This can be explained only on the ground that the molasses first separated is still in a supersaturated condition. It may be that a certain degree of supersaturation is necessary to force crystallization and that a very heavily concentrated molasses never reaches the point of exact saturation. Such a condition suggests that it might be possible to mix a little water with a massecuite in such a way that some of it at least would be used up in reducing the supersatura-

tion of the molasses and would not dissolve sugar. Our experiments along this line lead me to believe that if a massecuite is to be dried at 95 Brix there probably is a practical advantage in boiling to a higher Brix and diluting to 95, but that the gain is in time only. If two similar massecuites, one of 95, the other of 98 Brix, were crystallized for six months, then the 98 reduced to 95 with water, the molasses purities from each should be the same. Similarly, a prolonged boiling undoubtedly shortens the period required for practical crystallization, though ultimately two massecuites of the same Brix and composition must yield exactly the same purity molasses.

Mr. B. B. Henderson made some very careful tests on the rise in purity caused by adding water in our crystallizers. Water was added in varying amounts, taking from 6 to 24 hours to add one barrel to a 700 cu. ft. crystallizer. A summary of his results is:

% water	2.6	2.5	2.2	1.8	1.6
Original purity of separated molasses	29.5	30.1	31.6	30.5	32.0
Purity after adding water	32.5	31.8	33.0	32.4	33.1
Increase in purity	3.0	1.7	1.4	1.9	1.1
Increase for each per cent water added	1.15	0.68	0.64	1.06	0.69
Hours in crystallizer after adding water before separating	6	12	6	48	42

He concludes that, very roughly, one per cent of water increases the molasses purity by one point.

Viscosity of Molasses.

Mr. Henderson also made a large number of tests on the viscosity of molasses, and the effect of varying the Brix and the temperature.

He made use of the falling sphere method, using the length of time taken by a steel ball to fall through a definite depth of molasses as a measure of viscosity. The method was found very difficult to manipulate so as to get concordant results, but averaging a number of tests he reports that, working with a molasses of 93.6 Brix and 32.4 apparent purity, within the limits of 27° and 43° C., heating a molasses 4° reduces its viscosity to about the same extent as adding 1% of water. One per cent of water on the molasses in a massecuite is equivalent to about 0.7% water on the massecuite.

The average of a good many tests here has shown us that heating a massecuite 5° C. raises the purity of molasses about 1 point. Heating it 4° would raise the purity of the molasses 0.8, while adding 0.7% water would raise it 0.7 point, so from this calculation there is very little choice between water and heat, either as regards their benefits or their harm.

As stated, these are all very rough calculations, and should only be regarded as a first attempt to reduce to figures what has previously been left largely to guesswork. It is evident that a great deal more data from different factories will be needed before we really can know much about the subject.

Laboratory Accounting.

Mr. Foster has sent in a set of the card forms he uses for routine reports and control.

Mr. Elliot sends a blank form and the method used at Hakalau for calculating solids and sucrose balances.

MILL REPORT
HAKALAU PLANTATION CO.
TOTAL SOLIDS and TRUE SUCROSE BALANCE

For the ....weeks ending..19.....

Tons of Mixed Juice, gross weight		
Tons of Dry Press Cake		
°Brix of Mixed Juice		
°Brix of Theoretical Clarified Juice		
% Precipitated Soluble Solids		
Tons Precipitated Soluble Solids		
Gross Wt. M. J. .... tons X .... % Precipitated Solids	=	
Tons Lime Used		
Tons Soluble Solids in Press Cake Juice		
Tons Total Soluble Solids in Press Cake		
Tons Dry Press Cake		
Tons Total Soluble Solids in Press Cake	−	
Tons Insoluble Solids in Press Cake		
Tons of Mixed Juice, gross weight		
Tons of Insoluble Solids in Press Cake	−	
Tons of Mixed Juice, net weight		

TOTAL SOLIDS BALANCE

Net Weight of Mixed Juice	
Brix of Mixed Juice	
Tons Soluble Solids in Mixed Juice	
Tons Lime Added	
Total Tons Soluble Solids in Mixed Juice	
Tons Soluble Solids in Press Cake	. %
Tons Soluble Solids in Sugar	. %
Tons Soluble Solids in Molasses	. %
Tons Soluble Solids in Undetermined Loss	. %
TOTAL	100.00 %

TOTAL SUCROSE BALANCE

Net Weight of Mixed Juice	
True Sucrose % Mixed Juice	
Total Tons True Sucrose in Mixed Juice	
Tons True Sucrose in Press Cake	. %
Tons True Sucrose in Sugar	. %
Tons True Sucrose in Molasses	. %
Tons True Sucrose in Undetermined Loss	. %
TOTAL	100.00 %
Purity of Undetermined Loss	

We are using a form of Sugar Boilers Record which is rather convenient for checking up individual strikes. They are made up of cheap paper, 100 perforated white sheets and 100 yellow sheets alternating in a book. The yellow sheets are carbon copies, retained on the pan floor; the white sheets are torn out and filed in the laboratory.

We tried out a new system of reporting on individual fields, last year, which has some good points. A sample page of the Field Book and a blank form for Distribution of Sugar to Fields are appended. We have found in the past that the actual sugar per cent cane produced comes very close to the calculated

PIONEER MILL COMPANY

SUGAR BOILER'S RECORD

Pan No.....................

Strike No.....................

Crystallizer No..................... ....19.......

Started graining..............m. Finished graining..............m. Time............h.............m.

Started boiling................m. Finished boiling................m. Time............h.............m.

Finished discharging..............m. Time............h.............m.

Total............h.............m.

Made from..of massecuite of ....Brix ....Pol. ....Purity.

Made from..of syrup of ....Brix ....Pol. ....Purity.

Made from..of seed of ....Brix ....Pol. ....Purity.

Made from..of remelt of ....Brix ....Pol. ....Purity.

Made from..of molasses of ....Brix ....Pol. ....Purity.

Remarks:..

....

....

....
Sugar Boiler.

Started drying.............m. Finished drying.............m. Time..............h...............m.

Massecuite of..................Brix ....Pol. ....Purity.
Sugar of..................Brix ....Pol. ....Purity.
Molasses of..................Brix ....Pol. ....Purity.

....19.......

FIELD________________

Commenced________________ Finished________________

		TONS CANE	PER ACRE	TONS SUGAR	PER ACRE	Tons Cane Per Ton Sugar 96°
________ Acres Plant						
________ " Rattoon	Yield					
________ " Total	Estimate					

DATE	CANE ____ TONS	MILL JUICE Brix	Pol.	Purity	CANE % Fiber	Pol.	BAGASSE Pol.	% Moist	Q.R.	TONS SUGAR

MILL REPORT

PIONEER MILL COMPANY

Distribution of Sugar to Fields

For the ____4 weeks____ Ending ____May 29th____ 1920 Crop 1920

Fields	Tons Cane	Q. R.	Tons Sugar Calculated	Adjustment	Tons Sugar Actual

"Quality Ratio," and have made use of this in calculating field yields, going direct from "Quality Ratio" calculated from crusher juice to tons sugar calculated due a field without any intermediate steps. Stock is taken in the factory on the last Sunday in each month and the sugar made and in process reported for the period on the usual forms. The tons cane and average quality ratio of each field ground during the period are entered on the distribution sheet, the total tons calculated sugar from all fields added up, and across from it is set down the total sugar actually made. The difference is the total adjustment, which is apportioned rapidly to each field according to its proportion of total calculated sugar. The sum of the individual figures under "Adjustment" and "Tons Sugar Actual" must check up with the totals, previously entered.

The method does not take into account the influence of variation in fiber in different fields on extraction, but where 15 or 20 different fields are ground in the same day this is impossible to do with accuracy anyway.

At the end of each month all fields finished during that month can be reported on finally. No further adjustment is required at the end of the year.

Ammonium Nitrate, a New High-grade Fertilizer.

Ammonium nitrate is attracting a good deal of attention just now as one of the promising nitrate fertilizers. This compound had been made in Norway, where electric power was fairly inexpensive, for a number of years before the war started. One of the most modern plants is illustrated here, and shows the scale upon which the industry is conducted.

With the beginning of the world war the demand for nitrates for the manufacture of munitions increased enormously. At the same time, the shipment of sodium nitrate from Chile was greatly interrupted by the submarine campaign and the shortage of ocean tonnage. The manufacture of ammonium nitrate was taken up by all the warring countries, and now that the war demand has ceased, agriculture can benefit by the valuable supply of high grade fertilizer.

Several processes for the manufacture of ammonium nitrate were brought to a high state of efficiency both by the Allies and the Germans. Under ordinary conditions the nitrogen of the atmosphere is absolutely useless for animals and all plants except the legumes. In the electric arc, under a high pressure, it can be made to combine with hydrogen to form ammonia. Part of the ammonia formed can be easily oxidized to nitric acid and this acid unites with ammonia to form a neutral salt, ammonium nitrate. Thus the nitrogen in the two more or less troublesome liquids is changed into a safe, convenient salt. This salt has the great advantage that it is very concentrated and so is extremely economical to ship. It contains about thirty-four per cent of nitrogen which is equally divided between ammonia nitrogen and nitrate nitrogen. Compared with this high nitrate content, ammonium sulfate contains about twenty and a half per cent of nitrogen, and sodium nitrate about fifteen and a half per cent.

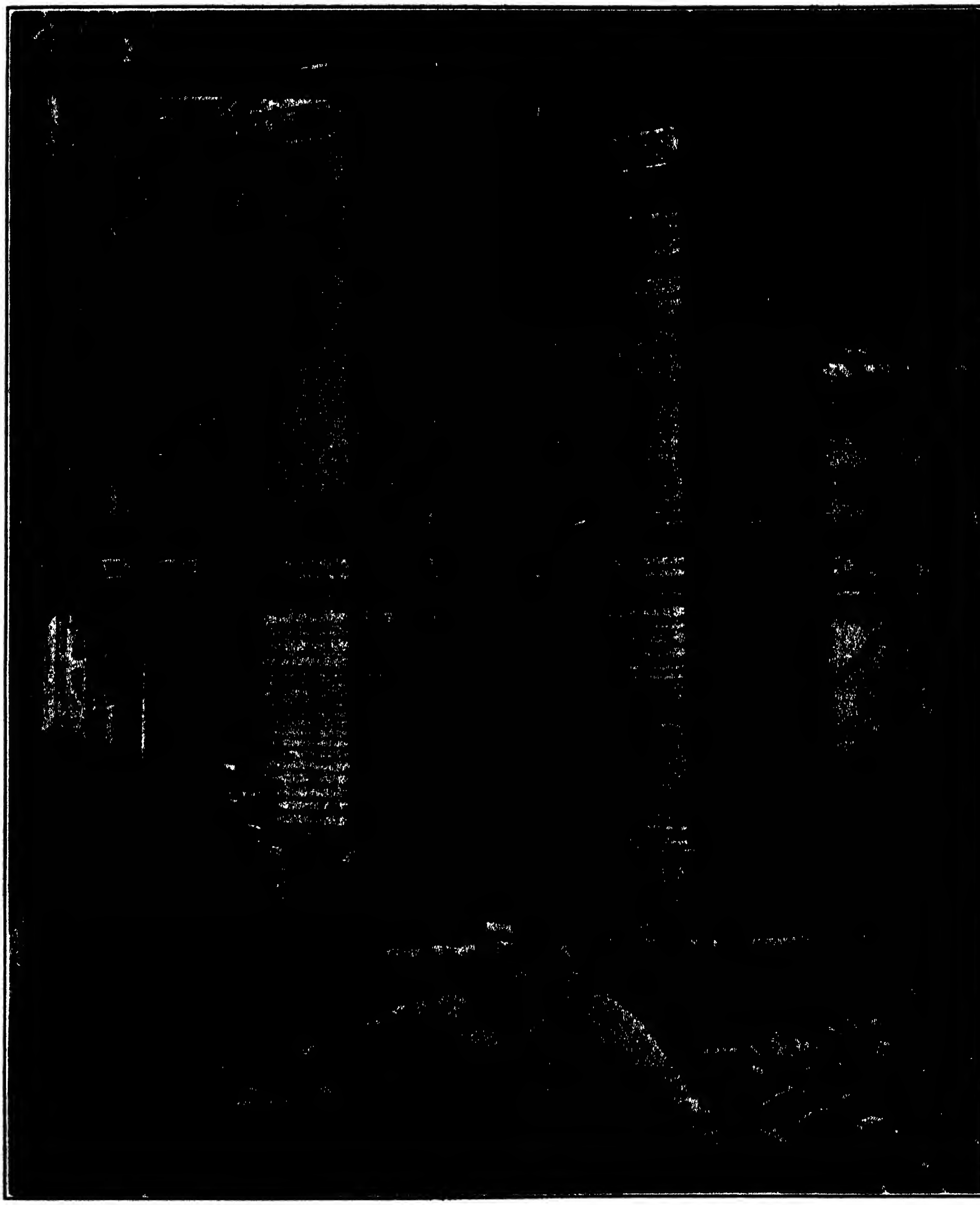
Ammonium nitrate manufacture, Norway. The Saaheim power station.

Applying ammonium nitrate to the soil is really equivalent to making a combined application of sulfate of ammonia and of high grade nitrate. All of the compound is capable of being absorbed by plants. It therefore should not have the effect of turning soils acid as does sulfate of ammonia, or tending to make them alkaline like nitrate of soda.

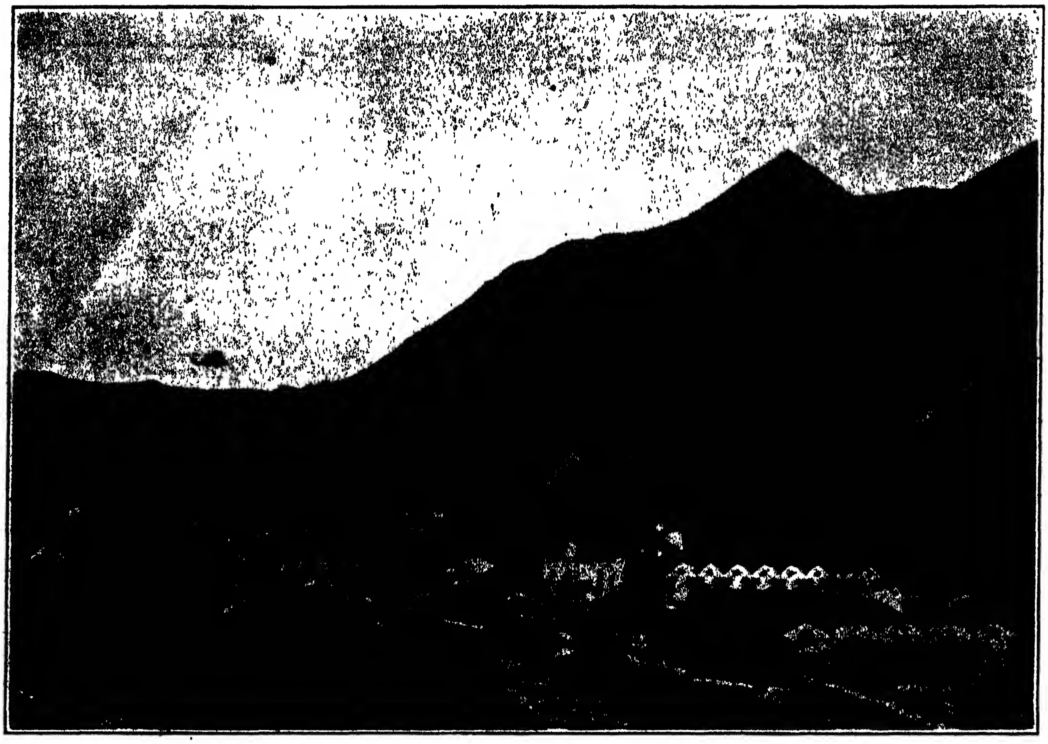
Several experiments have recently been carried out, in various parts of the world, in which ammonium nitrate has been compared with the ordinary fertilizing salts. E. J. Russell, writing in the Journal of the Board of Agriculture, described a series of field tests at Rothamsted and other parts of England. Potatoes, mangolds, and wheat were the crops grown and ammonium nitrate was in each case compared with sulfate of ammonia. The results of these experiments show that the new nitrate is a valuable fertilizer. It was more effective than the sulfate on mangolds and equally effective on wheat. The nitrate appeared to be somewhat inferior to the sulfate for potatoes.

Bachelier in France compared ammonium sulfate, ammonium nitrate, and sodium nitrate in field experiments upon sugar beets. Ammonium nitrate gave equally good results per unit of nitrogen.

Hendrik in Scotland recently compared calcium nitrate, sodium nitrate, ammonium sulfate, ammonium nitrate, and cyanamid. He grew crops of hay and oats on several different soils and obtained at least as good results with ammonium nitrate as with the other forms of nitrogen.



Granite towers in which the nitric oxides are combined with waters during the formation of the nitric acid.



Rjukan factories and town in the background.

Malpeany in France made pot tests on sugar beets, oats, and potatoes, with sodium nitrate, calcium nitrate, ammonium nitrate, ammonium sulfate, and cyanamid. In these tests calcium nitrate gave the best results, followed by sodium nitrate, and cyanamid, only slightly lower.

Only one experiment with ammonium nitrate on sugar cane has been reported. This was made by Easterby in Queensland. He compared dried blood, sulfate of ammonia, calcium nitrate, ammonium nitrate, and nitrate of soda. The fertilizers were applied to the plant crop at the rate of 100 pounds of nitrogen per acre. The yield in tons of sugar per acre was as follows: dried blood 8.5; ammonium sulfate 7.9; calcium nitrate 7.8; ammonium nitrate 7.4; and nitrate of soda 7.3 tons, respectively.

The above experiment was not carried out on Hawaiian soil, but tests under way at the Waipio Substation indicate that ammonium nitrate is a fitting substitute for nitrate of soda. The new material, without doubt, deserves a thorough trial.

G. R. S.

SUGAR PRICES FOR THE MONTH

Ended January 31, 1921

	96° Centrifugals		Beets	
	Per Lb.	Per Ton.	Per Lb.	Per Ton.
Jan. 3, 1921*	5.385¢	$107.70		
" 4	5.520	110.40	No quotation.	
" 7	5.510	110.20		
" 8	5.520	110.40		
" 11	5.550	111.00		
" 12	5.520	110.40		
" 17	5.515	110.30		
" 18	5.425	108.50		
" 19	5.390	107.80		
" 21	5.385	107.70		
" 22	5.390	107.80		
" 25	5.270	105.40		
" 26	5.135	102.70		
" 27	4.930	98.60		
" 28	4.890	97.80		
" 29	4.885	97.70		
" 31	4.855	97.10		

* The previous fluctuation was that of December 28, 1920, when the price changed from 5.31 to 5.32 cents.

[D. A. M.]

THE HAWAIIAN PLANTERS' RECORD

Volume XXIV. MARCH, 1921 Number 3

A monthly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

Transference of Nematodes (Mononchs) from Place to Place for Economic Purposes.

[*The following article from "Science," June 25, 1920, by Dr. N. A. Cobb is of interest because it advocates the handling of nematode problems on the same line as we have handled our insect problems for some years. The writer discussed this subject with Dr. Cobb three years ago in Washington, and we agreed that the Hawaiian Islands offered as good a field for this experiment as they do for similar ones in entomology. Unfortunately, we have not the same knowledge of the systematic aspects of our nematodes as we have of our insects, and so the problem could not at present be handled with the same confidence. To enable us to work with equal confidence we should have to make a fairly good survey of the nematodes of the Islands.*

The technique necessary to handle these animals is more delicate than with insects, and precautions to keep out harmful nematodes would have to be taken. But both these points could be overcome. Where heavy loss of crops is due to nematodes the question is worthy of serious attention.—F.M.]

Speaking generally, it is now beyond question that many soil-inhabiting mononchs feed more particularly on other nemas. However, they never follow these latter into plant roots, except in the case of open root cavities fairly readily accessible. They do not enter living plant tissues in pursuit of their prey. It follows that the good they do is in devouring the larvae and young of injurious nemas at such times as the latter are accessible either in the soil or in open cavities in the roots of plants.

In transferring mononchs from place to place with a view to making use of them in combating injurious nemas, the first requisite is a supply of mononchs. Such a supply may be obtained from soils in which the mononchs are numerous, and although we have comparatively little experience to guide us, yet it is now demonstrated that supplies of mononchs existing under these conditions are avail-

able. Thus far these supplies have been discovered more or less by accident; the cases, however, are numerous enough to establish the belief that special search will lead to the discovery of a sufficient number of these original sources of mononchs to furnish an adequate supply for trial.

The methods for collecting the mononchs, and transferring them, once they have been found, have been sufficiently elaborated for practical purposes, and published.

In transferring the mononchs to new situations, it is, of course, best to pay careful attention to the relative physical and biological conditions of the two habitats—the soil from which they are transferred and that to which they are transferred. The physical and biological conditions of the two habitats should be such as to insure the persistence of the mononchs after they have been transferred from the old to the new habitat. If the climatic and soil conditions of the new habitat closely resemble those of the old habitat, there is every reason to suppose that the mononchs will survive and flourish if there is a supply of suitable food.

The practical details may be illustrated by a hypothetical example. Suppose a region in Holland having a sandy soil has distributed in it as a plant pest the devastating nema, *Tylenchus dipsaci,* which, though more or less prevalent, is not doing very serious damage because held in check by mononchs. Suppose the existence of another region, like that in the vicinity of Bellingham, State of Washington, U. S. A., having a soil and climate similar to that of the district in Holland just mentioned, and suffering more or less severely from the ravages of *Tylenchus dipsaci* because this nema is not sufficiently held in check by any natural force. We may suppose that in this latter case *dipsaci* has been introduced at Bellingham without the enemies and parasites that hold it in check in the first-mentioned place. The mononchs found in the soil of the Holland district feeding upon *Tylenchus dipsaci* are collected and transported to Bellingham and introduced into the soil. There is good reason to suppose that under the new conditions, finding their food abundant, including the larvae and young of *Tylenchus dipsaci,* the mononchs will flourish and keep *Tylenchus dipsaci* in check.

If it be asked why injurious nemas are transferred from place to place without their enemies being transferred at the same time, the answer is that nemas injurious to plants are often transferred in the interior parts of plants imported in a living condition, and, as already indicated, the mononchs and other predatory nemas are less common in these situations than they are in the adjacent soil, which latter in the course of commerce often is removed from the roots and not shipped. One need only instance the case of bulbs and similar importations to see how much better chance the injurious parasitic nemas have of being imported than have those nemas which feed upon them. There is also reason to believe that sometimes the parasitic nemas infesting crops are more resistant to untoward conditions, e. g., dryness, than are the predaceous nemas.

We have at the present time arrived at a stage where logically the next step is to try out the introduction of promising species ~~of~~ mononchs. Efforts of this kind will necessarily be somewhat expensive, probably more expensive than the corresponding early efforts to introduce beneficial insects. There can be no doubt, however, that the enormous losses due to plant-infesting nemas fully

justify the expenditure of even large sums of money in an effort to apply this remedy, more particularly because the remedy, when successful, bids fair to be permanent and self-sustaining.

After long-continued and intensive studies I am thoroughly convinced that many of the practises evolved in the transfer of beneficial insects can, with appropriate modification, be applied to the nemas. At the present time the greatest drawback in the case of the nemas is the small number of people who are technically competent to make the necessary biological examinations. It is in this respect principally that their introduction will differ from that of the introduction of useful insects, for the nema problem is essentially a microscopic one. Though the collection of the nemas from the soil differs entirely from the collection of beneficial insects, the methods have already been brought to such a state that there are no insuperable obstacles.

The percentage of mononchs in miscellaneous collections of soil-inhabiting nemas taken from various situations is roughly indicated by the following figures based on the writer's examinations—in each case of from one thousand to several thousand specimens:

1. Miscellaneous collection from very small quantity of soil taken from the roots of 14 species of plants imported from Brazil, 6.5 per cent mononchs.
2. Sandy soil about the roots of astilbe and peony, Holland, 11.6 per cent mononchs.
3. Soil from cornfield in New Jersey in autumn, the prevailing genus was *Mononchus*.
4. Sand from Washington filter beds, 96 per cent mononchs.

N. A. Cobb.

U. S. Department of Agriculture.

Some Chemical Aspects of Soil Fertility.*

By Frank T. Dillingham.†

Soil fertility may be defined as the ability of a soil to produce and to maintain good crop yields. This ability of the soil to produce and to maintain good crop yields depends upon a number of factors which may be classed under three heads: (a) chemical, (b) biological, (c) physical. Soil fertility may also be defined as that condition of a soil which makes it productive. The elements of soil fertility are a full supply of available plant food, a suitable and continuous supply of moisture, and a good physical condition of the soil.

It is the purpose of this paper to consider some of the more important chemical and biological factors involved in soil fertility. It will be well first of all to present briefly a few of the commonly accepted ideas concerning the chemistry of soil formation, but in discussing the chemical agencies it is prac-

* A lecture presented at the University of Hawaii, Short Course for Plantation Men, October, 1920.

† University of Hawaii.

tically impossible to avoid mention of certain physical agencies in this connection because of the intimate relationship between the two types of forces.

Soils as we know them today have been and are being derived from rock materials on the surface of the earth. When in the molten state, our globe was surrounded by huge masses of water vapor which upon condensation descended in torrents upon the molten rock mass to be immediately converted into steam which rising into the air was again condensed into water, in turn to fall again upon the earth's surface. The ultimate effect of this action, repeated an infinite number of times, was to cool down the surface of the earth to such a point that various forms of life could appear. While this action was mainly physical, chemical changes undoubtedly occurred in the rock masses through solvent action of the water which must have held oxygen, carbon dioxide, oxides of nitrogen, and other gases in solution.

Bacteria were probably the first forms of life to appear. Investigation has shown that such organisms exert an important influence in aiding rock decomposition. It appears that these minute forms of life utilize carbon from atmospheric carbon dioxide as do higher plants, and also utilize ammonium carbonate forming organic matter from it and liberating nitric acid. These organisms are able to penetrate every little crevice produced by weathering agencies, and acting throughout long periods of time produce results of considerable geological importance. They act upon rock fragments, constantly reducing them to smaller and smaller sizes. Each fragment loosened from the rock mass is found covered with a film of organic matter, and the accumulation begun by these apparently insignificant forces is added to by the remains of plants of higher orders which come as soon as nutriment and standing room are provided.

After bacteria there appeared low forms of plant life such as lichens and mosses, which, growing upon the rock masses sent their tiny rootlets into every crevice seeking not merely foothold but food as well. Slight as such action was it promoted the disintegration of rock. The plants died and others grew upon their remains; thus there accumulated, often with extreme slowness, a thin layer of humus which retained moisture from rain bringing the rock under the influence of chemical action and also furnished small amounts of organic acids which acted as solvents. In the course of time enough soil accumulated to furnish standing room for larger and higher types of plant life which exercised even more powerful action. In case of rocks in a jointed condition, the roots of plants pushing downwards enlarge the crevices by virtue of their gain in bulk from day to day and thus furnish more ready access for moisture to hasten the disintegration.

The physical and chemical action of the roots of plants is enormous in the aggregate. The direct chemical action of this agency is said by some investigators to be due to organic acids exuded from the roots; the exact nature of these acids is not accurately known, but it is considered possible that a variety of organic acids exists in the rootlets of each species of plants. On the other hand many investigators hold that the corrosive effect of root action is due largely, if not wholly, to carbonic acid.

The chemical action of water, especially in connection with the atmosphere as an agency in the formation of soils may be considered briefly under four heads;—(1) oxidation, (2) deoxidation, (3) hydration, and (4) solution. (1) Oxidation is noticeable only in rocks containing iron as sulphide, ferrous carbonate, or silicate Such an oxidation is often accompanied by an increase in bulk, so that even if nothing escapes by solution there may enter a powerful physical agency to aid in disintegration. As the oxidation continues the minerals become gradually decomposed and fall away into unrecognizable forms. (2) Deoxidation is less common than oxidation. Water containing small amounts of organic acids may reduce higher oxides to lower forms and change ferrous sulphates into sulphides, a process which probably takes place in marine muds. (3) Hydration usually accompanies oxidation and is an important agency in the disintegration of rock. This is particularly true in the case of micaseous sandstones and granitic rocks. Such a change, provided that it is not attended by a loss of constituents by solution or erosion, is often accompanied by an appreciable increase in bulk. In the transition of a granitic rock to arable soil it has been estimated that an increase in bulk amounting to 88% may take place. (4) The solvent action of water is probably the most important of its immediate effects. We must consider the action not of pure water, but of water containing various salts, acids, and gases which it has taken up in passing through the atmosphere and in filtering through the layer of organic matter and decomposition products which cover such a large portion of the surface of the land. The presence of these various substances in solution enormously increases the solvent action of water. Of all the mineral substances acted upon, limestones are the most easily affected, but it has been conclusively shown that all the ordinary rock forming minerals, silicates, oxides, and carbonates, are appreciably soluble in the water of rainfalls and at ordinary temperatures. Through the decomposition of iron pyrites there may be formed free sulphuric acid, or through the decomposition of a felspar there may arise carbonates of the alkalies, any of which, when in solution, are more energetic factors in promoting decompostion than water alone. Hence, under certain conditions, the process of decomposition once set in operation increases until such a depth is reached that the percolating solutions become neutralized and further action, aside from hydration, practically ceases.

Naturally soil moisture, with its content of soluble salts must tend to bring about chemical action in the nature of double decomposition. This is particularly true in regard to the action of such solutions upon the so-called zeolites. Zeolites are secondary minerals resulting from chemical changes taking place in pre-existing rocks, and indicate the first stages of rock decay; they are hydrous silicates of alumina, with varying percentages of lime, potash, and soda. These are the chief soil constituents to which the power of a soil to fix or retain bases from solutions is due.

The ordinarily feeble action of the air upon rocks is greatly increased by natural temperature variations. Rocks are complex mineral aggregates of low heat conducting power, each constituent of which has its own ratio of expansion or contraction. As the temperature rises each and every constituent expands and crowds against its neighbor; as the temperature falls a

corresponding contraction takes place. Slight as such movements may seem they are sufficient in time to produce a decided weakening effect, and serve as a starting point for other physical and chemical agencies. Such action is especially noticeable in regions where a cloudless sun heats the rocks so highly as to be uncomfortable to the touch and where at night the temperature sinks nearly to the freezing point.

The formation of humus from the remains of plant and animal life is largely dependent upon the chemical action of bacteria which in turn is controlled by climatic conditions. Thus in warm, not too moist climates, a mild, rich type of humus may be formed; while in cold, wet climates a sour, unfriendly type of humus results. The importance of humus in soil formation may be summed briefly as follows. It serves as a storehouse of nitrogen in the soil. It furnishes nutriment for bacteria and other forms of life. It produces carbon dioxide and other acids in its decay which increase the solvent action of soil moisture on soil constituents. It improves the physical condition of both light and heavy soils.

Ants by their numerous borings, penetrating at times to depths of many feet, bring about not only a rearrangement of soil particles, but also a condition of porosity whereby air and water gain access to the deeper lying portions, thereby promoting further chemical and physical changes. These creatures carry large quantities of organic matter into the soil and this, in addition to the excretions of the ants themselves, tends to further the processes of decomposition.

According to Darwin, the common earthworm produces widespread and beneficial results. These creatures burrow in moist, rich soil and derive their nutriment from the organic matter which it may contain. In order to obtain this comparatively small amount of nutritive material they devour the soil without any selective power and pass it through their alimentary tracts rejecting the non-nutritious portions which nearly equal in bulk that first taken in. While the main influence of the worms is seen in a mellowing by burrowing and in a transfer of materials from a lower to a higher level, they bring about a slight admixture of organic matter by dragging down small fragments of leaves and grasses, which, when taken into account with their excrement, must tend to enrich the soil to a greater or less extent. Darwin states that in certain parts of England these worms bring to the surface every year, in the form of excreta, more than ten tons per acre of fine dry mould. By collecting and weighing the excretions deposited on a small area during a given time he found that the rate of accumulation was an inch in every five years. The importance of worms both as mellowers of the soil and as levelers of inequalities is, therefore, not to be overlooked.

Thus we see that the soil is a very complex substance made up of more or less completely disintegrated rock fragments, with comparatively small amounts of organic matter derived chiefly from the decomposition of plant and animal remains, and supplied to a greater ~~or less~~ degree with moisture, and having a fauna and flora peculiar to itself.

By far the greatest portion of the soil is composed of inorganic or mineral matter, largely of a nature insoluble in water, hence not readily available.

This constitutes the so-called inert matter of the soil. The chief functions of this mass of inert matter are as follows: (1) To furnish standing room for crops, or a medium for their development of roots; (2) to serve as a reservoir for moisture; (3) to aid in regulating temperature by absorbing and radiating heat; (4) not the least in importance is the fact that this enormous mass of inert matter constitutes a storehouse of mineral constituents, including those which are necessary or essential for plant growth. These mineral constituents are mainly in a "locked up" or unavailable condition, and it is an important part of the agriculturalist's business to learn how to unlock and to render available these necessary ingredients for the use of crops. In other words, it is his business not only to maintain but to increase soil fertility. Some of the ways in which this may be done are by means of: (1) thorough tillage; (2) supplying humus or organic matter in the form of farmyard manure, in the form of green manuring, or by plowing in trash, stubble, and crop residues; (3) proper choice and application of fertilizers; (4) rotation of crops combined with fallowing when necessary.

It will be well to consider these points somewhat more fully. (1) The importance of thorough tillage can hardly be overestimated. Plants take their mineral constituents from the soil in the form of very dilute solutions, tillage promotes the formation of such solutions by exposing fresh surfaces to the solvent action of atmospheric and soil moisture. Tillage promotes the oxidation and aeration of the soil. It increases the activity of useful forms of bacteria, especially those which form ammonia and nitrates and those which fix the free nitrogen of the air. When properly conducted tillage has a beneficial effect upon the physical character of soils.

(2) The supplying of some form of organic matter which may be converted into soil humus by various soil agencies is of great importance also. Some investigators have emphasized this point particularly in connection with our Hawaiian soils. The benefits conferred upon a soil by humus are briefly as follows:—It furnishes a storehouse of nitrogen in organic combinations. This organic nitrogen is acted upon by useful bacteria and converted into ammonium compounds and nitrates which may be utilized by the crops. Humus furnishes nutriment for soil bacteria themselves and for other forms of life which in turn act upon various soil constituents unlocking them and rendering them available to plants. By its own proper decomposition humus produces carbon dioxide and other acids which increase the solvent action of the soil moisture, thus aiding in further disintegration of soils. It increases the retentiveness of light soils for moisture and improves the physical texture of both light and heavy soils. An abundant supply of humus tends to render a soil productive even though only small quantities of available mineral constituents are present.

(3) Agricultural chemists have proved that there are eleven chemical elements which are absolutely essential for normal plant growth. By an essential element is meant one in the entire absence of which a plant cannot develop properly. These eleven elements are carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, chlorine, iron, calcium, magnesium, and potassium, which must be supplied in proper combinations. Of these eleven

elements but three, namely nitrogen, phosphorus, and potassium, need ordinarily give the agriculturalist any concern; these three are sometimes present in soils in such small quantity that their deficiency must be met by the addition of these elements in some available forms. They are usually added in the form of stable manure or as commercial fertilizers.

(4) Concerning rotations and fallowing it is not easy to make any definite statements as conditions differ so much in various places. It may be sufficient to call attention to the fact that under natural conditions, that is, when land is left to itself for a long series of years it often tends to increase in fertility. Part of this increase in fertility is due to the fact that amospheric nitrogen is fixed or combined by certain forms of soil bacteria and is then turned over to the soil; then, too, nature usually slips in various forms of legumes to help out what may be called a natural form of rotation.

There are certain constituents of soils which are concerned in maintaining soil fertility and which deserve more than a passing notice. These are the soil constituents to which the ability of a soil to fix or absorb bases is due. These constituents are known as zeolites. Chemically they are hydrated, double silicates of alumina and potash, or soda, or lime. They have power to absorb or fix, in rather loose combination, the bases ammonia, potash, and lime which may be applied as fertilizers, and thus to retain them in forms which are not easily leached out by water, but which can be appropriated by the roots of plants. Phosphoric acid when applied to a soil is usually fixed by certain basic constituents such as lime, ferric oxide, and alumina. Because of the high content of iron and aluminium oxides in our soils here, they have large absorptive or fixing power towards soluble phosphates.

In relation to crops, that constituent of the soil of immediate importance is the soil moisture since it is from this solution that plants through their roots draw all the material involved in their growth except the carbon dioxide and oxygen absorbed through their leaves. That is to say, the soil solution is the natural nutrient medium from which plants absorb the mineral constituents which have been shown to be absolutely essential to their continued existence and growth. Since this is the case it would be of the greatest value if the soil solution could be obtained from the soil exactly as it exists there. This is not possible of accomplishment as yet, though many efforts to approximate it have been made.

Some of the methods employed for this purpose are briefly as follows: (1) Extraction of masses of soil with water. One of the chief difficulties with this method is due to the fact that different extracts are obtained varying with the quantities of water employed. Such extracts are not true representations of the actual soil solution since they are the resultants of the solvent action of the soil moisture and the fixing or absorptive power of the soil. (2) By means of powerful centrifuges and saturated soil it has been possible to throw out the excess of solution over the critical water content of the soil. In this way small quantities of solutions, usually a very few cubic centimeters at a time, have been obtained. This is due to the fact that the soil solution, under conditions suitable for crop growth, is held by a force of great magnitude. (3) Displacement of the soil solution from soils in steel cylinders by forcing in oil under

high pressure has been tried. This appears to be a promising method and is under investigation by a number of soil scientists.

Quite recently the Bureau of Soils has been conducting some extensive investigations concerning the nature and functions of the soil solution and have published the results of one phase of the investigation in a recent number of the Journal of Engineering and Industrial Chemistry (Vol. 12, No. 7, p. 663), under the title, "Solid Phases Obtained by the Evaporation of Certain Soil Extracts." Briefly, the procedure consisted of taking from 400 to 2000 pounds of soil and treating it in portions of 25 to 50 pounds with from three to five parts of distilled water to one part of soil. After thorough agitation in a barrel-type churn the coarser material was allowed to subside for some hours and the liquid portion was then filtered through Pasteur-Chamberland filters. The clear solution was then evaporated in a steam-jacketed, tin-lined copper kettle until the specific gravity became notably higher, but before any crystalline salts except calcium carbonate and calcium sulphate were deposited on cooling. At this point the solution was poured into porcelain-lined dishes and evaporation was allowed to proceed at low temperature. As evaporation proceeded, crops of crystals were successively produced and separated from the liquid by filtering through paper filters. Usually from 10 to 15 crops of crystals were thus separated. The crystals were dried and the identifications were made by microscopical examination and petrographic methods.

The results indicate that the so-called plant foods are present in the complex mixture of single, double and triple salts entirely unlike the conventional combinations that chemists have heretofore assumed them to be.

It would appear from an examination of all the data that are available that the types of salts which have been found in the soil extract have a general resemblance to the deposits at Stassfurt and the inland sea and lake deposits which have been studied throughout the world. This is not at all surprising when we realize that the ultimate source of these deposits is the soil and that they have accumulated as a result of the evaporation of enormous quantities of river and sea waters that transported these soluble materials from soil sources. It would appear, therefore, that the soil is, in fact, a miniature Stassfurt deposit differing in detail with the character of the rocks and the processes of disintegration at certain points. Among the crystalline salts thus far identified as occurring in soils are such well-known minerals as sylvite, carnallite, and kainite.

This study throws a new light upon the soil solution, and is of much interest to the soil chemist. It opens up a large field of research as to the occurrence of particular types of salts and the possible significance of their presence on plant nutrition; also the possible change in the system by the addition of lime and fertilizer materials.

Certain forms of bacteria are so intimately associated with soil fertility that a brief discussion of soil bacteria should not be out of place.

Many changes take place in the nitrogen of the soil which are brought about by bacteria living in the soil. First of all there is the transformation of organic soil nitrogen into ammonia, which is known as ammonification. Next is the change of ammonia to nitrites, and of nitrites to nitrates, a change called nitrification. Under unfavorable conditions another change is possible; a change in-

volving the destruction of nitrates, either nitrites, ammonia, protein, or free nitrogen being formed. Such a change is known as denitrification. A further change is the production of organic nitrogenous compounds from the elementary nitrogen of the air; that is designated as nitrogen fixation.

Organic matter by decay is converted finally into carbon dioxide, water, ammonia or nitrates, and mineral salts. The general movement of organic soil nitrogen is towards the formation of nitrates, through ammonia, in spite of the presence of bacteria which act in the reverse direction.

Bacteria which affect soil nitrogen have been divided into seven groups, as follows:

(1) Bacteria which decompose organic nitrogenous substances and produce ammonia. This change is known as ammonification.

(2) Bacteria which oxidize ammonia to nitrites.

(3) Bacteria which oxidize nitrites to nitrates. These groups, 2 and 3, work together and produce the change known as nitrification.

(4) Bacteria which reduce nitrates to nitrites and ammonia.

(5) Bacteria which reduce nitrates to nitrites, and the nitrites to free nitrogen. These groups, 4 and 5, usually work together and produce the change known as denitrification.

(6) Bacteria which change ammonia, nitrites, or nitrates into protein or bacterial body substances. Bacteria of reduction.

(7) Bacteria which fix atmospheric nitrogen and cause it to form compounds. Bacteria of fixation.

A large number of different bacteria and moulds are capable of converting organic nitrogen into ammonia. Moulds probably do the larger part of the work in manure heaps and very peaty soils, but in ordinary cultivated soils bacteria predominate. The optimum or most favorable conditions for ammonification are a temperature of about 30 degrees Centigrade or 86 degrees Fahrenheit, complete aeration, and slightly alkaline reaction. The moisture and temperature conditions of the soil play an important part in determining the character of the bacterial flora and, therefore, the character of the chemical products formed. The mechanical and chemical constituents of the soil are also of decided influence.

Nitrification takes place in two stages or steps. First, nitrites are formed from ammonia; second, these nitrites are then changed to nitrates. Two kinds of bacteria are involved in this change, namely, the nitrous and the nitric organisms.

The optimum or most favorable conditions for rapid nitrification are: (1) A supply of suitable food such as potash, phosphoric acid, lime, sulphates, and carbon dioxide. (2) A suitable base or bases must be present, as the nitric acid must be neutralized as rapidly as produced, for the organisms will not thrive in an acid medium. Carbonate of lime is particularly useful for this purpose. On the other hand, too much or too strong a base is injurious. (3) Proper temperature must be maintained, as nitrification is most active at about 36 degrees Centigrade or 97 degrees Fahrenheit. It practically ceases at low temperatures. (4) Absence of strong light is important, as light tends to check the action of the organisms and finally destroys them. Hence a certain degree of shade is

necessary. (5) Freedom from salts in excess. It has been shown that large amounts of water-soluble salts are injurious to the activity of the nitrifying organisms. (6) An abundant supply of air or oxygen is necessary. A loose or porous condition of the soil is much more favorable than a compact condition. Thus a soil under cultivation allows more nitrification than a similar soil in pasture. As a rule conditions in Hawaii are favorable to nitrification.

The term denitrification is applied to the destruction of nitrates. Under certain conditions the nitrates in the soil are deoxidized with the production of organic bodies, nitrites, ammonia, or even free nitrogen. In this last case there is a loss of nitrogen from the soil. The conditions favorable for denitrification are as follows: (1) Insufficient supply of free oxygen. In water-logged soils or soils which are so compact that air cannot penetrate them, denitrification is very apt to occur. (2) The presence of a large amount of crude organic matter is objectionable. Cases are known in which a heavy application of fresh farm manure destroyed the nitrates in the soil and produced a smaller crop than if no manure had been applied. It is believed that a large increase in oxidizable organic matter favors denitrification, both by lessening the supply of free oxygen and by tending to rob the nitrates of their oxygen.

In conclusion I think we may see that instead of considering the soil as a mass of inert or dead material, we may look upon it as a complex mass of matter in the process of continual change and activity chemically, physically, and biologically.

In an article by C. A. Browne, entitled "Industrial and Agricultural Chemistry in British Guiana" (Jr. Ind. & Eng. Chem., 11, 874), he makes the following statement: "In its ultimate phase the study of soils is not simply an agricultural problem, as is sometimes imagined, but involves industrial and economic questions of greatest significance; for the soil, in whatever way we consider it, is that upon which not only manufactures and commerce, but all the phases of man's social life, depend. Probably no other kind of research requires the correlation of so many sciences; questions of geology, mineralogy, chemistry, physics, and meteorology are mutually involved, as well as those of biology and agriculture."

Report of Committee on Deterioration of Cane After Cutting.*

We give herewith a brief resumé of the report of Mr. Raymond Elliott, chairman of the Comimttee on Deterioration of Cane After Cutting. The report is filed at the Experiment Station and is available to anyone who may wish to study it in detail.

The report gives the results of twenty-three tests conducted on four plantations. Mr. Raymond Elliott reported the work from Paauhau Sugar Plantation Company, Mr. Henry L. White from Onomea Sugar Company, Mr. D. W. Richardson from Kilauea Sugar Company, and Mr. R. J. Richmond from Hawi Mill and Plantation Company.

* Presented at Eighteenth Annual Meeting of the Hawaiian Chemists' Association, held jointly with the Hawaiian Engineering Association, November, 1920.

The results of the individual tests are in some cases erratic and inconsistent. We believe this to be due to the methods of sampling. From work done here at the Station under very careful control we found that to get concordant results rather large samples must be used. Each bundle of cane should weigh at least 75 to 100 pounds and contain 40 or more sticks, which should be taken in consecutive order in the line; and rather than run samples every day, let it be every two days and interpolate between.

In summarizing the results, Mr. Elliott reports in part as follows:

The cane loses weight from the time it is cut until it is ground, although the conditions vary. When the weather is hot and with a breeze the loss in weight is at the maximum, whereas, when the atmosphere is saturated with moisture, the loss is lessened.

The difference between burned and unburned cane is distinctly seen at Paauhau and Kilauea.

The burned cane deteriorates faster than unburned cane, practically under the same conditions, with rainfall very slight in both places, for the first three days.

Taking the average after cutting for burned cane, the loss for the first day is 3.8%, representing five tests from three districts, variety Yellow Caledonia. For unburned cane, the loss for the first day is 2.52%, representing six tests from four districts, variety Yellow Caledonia.

For the second and third days the losses for burned cane are 8.88% and 9.67% as against unburned, which are 5.67% and 6.49% respectively.

The ratios in favor of not burning are: first day, 1.51; second day, 1.57; and the third day, 1.49.

Following are Tables 1 and 2, showing the averages for burned and unburned cane:

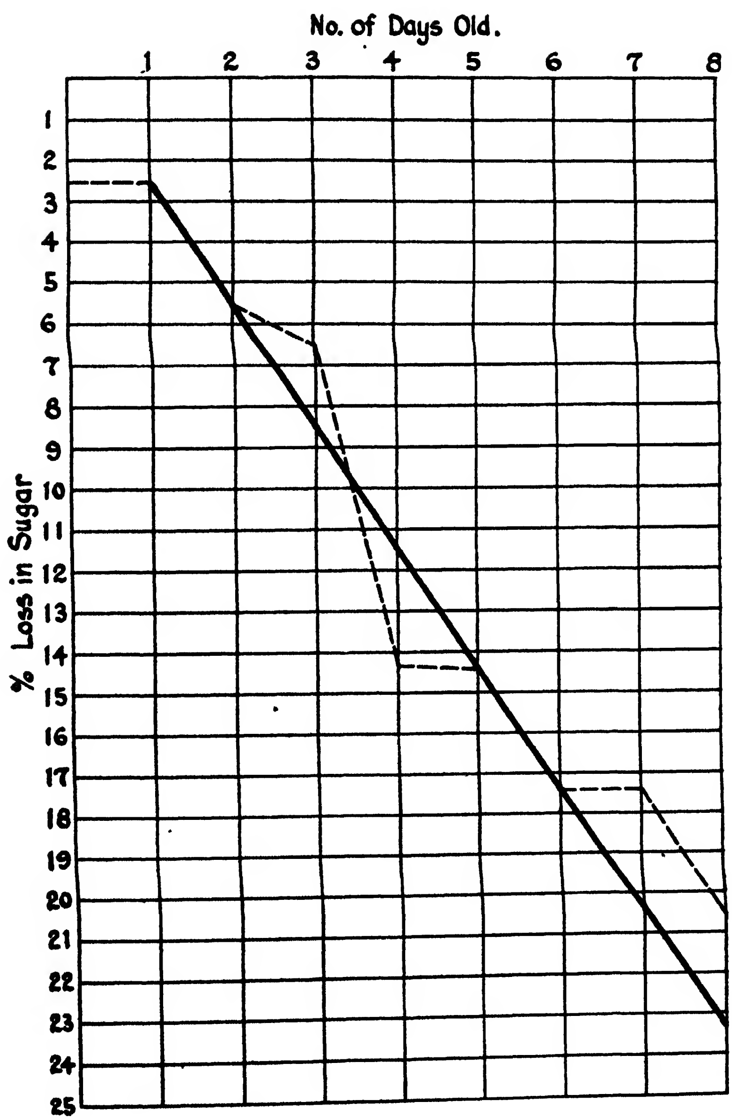
TABLE NO. 1.—BURNED CANE. VARIETY: YELLOW CALEDONIA.
% LOSS IN SUGAR.

Plantation	Exp. No.	No. of Days After Cutting							
		1	2	3	4	5	6	7	8
Paauhau	1	.46	8.17	18.77	16.93	13.87	18.09	18.04	19.03
Kilauea	1	+2.30	.....	+1.8	2.6	9.6			
"	3	5.76	18.10	18.51	32.02				
"	4	8.49	8.93	7.96	7.29	12.62	.....	17.20	
Hawi	1	6.6	.3	4.9	3.3	+1.5	19.9	+3.0	28.6
Average—10	....	3.80	8.88	9.67	12.43	8.63	19.00	16.12	23.82

TABLE No. 2.—UNBURNED CANE. VARIETY: YELLOW CALEDONIA.
% LOSS IN SUGAR.

Plantation	Exp. No.	No. of Days After Cutting							
		1	2	3	4	5	6	7	8
Paauhau	3	2.22	3.70	5.25	12.58	19.18	21.27	28.05	30.02
Onomea	1	1.20	8.20	7.20	8.0	7.5	4.8	10.3	9.2
"	2	2.10	2.90	+ .5	8.8	3.1	3.8	1.5	3.2
"	3	+4.00	.9	2.4	4.4	8.1	8.9	12.8	16.8
Kilauea	2	5.00	4.8	5.7	.....	12.6			
Hawi	2	8.6	13.5	18.9	37.6	36.1	48.2	34.2	43.6
Average—13	....	2.52	5.67	6.49	14.28	14.43	17.39	17.37	20.56

N. B.—Onomea's cane assumed as unburned.
+ = plus values.


No. of Days Old.
1
2
3
4
5
6
7
8
% Loss in Sugar
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
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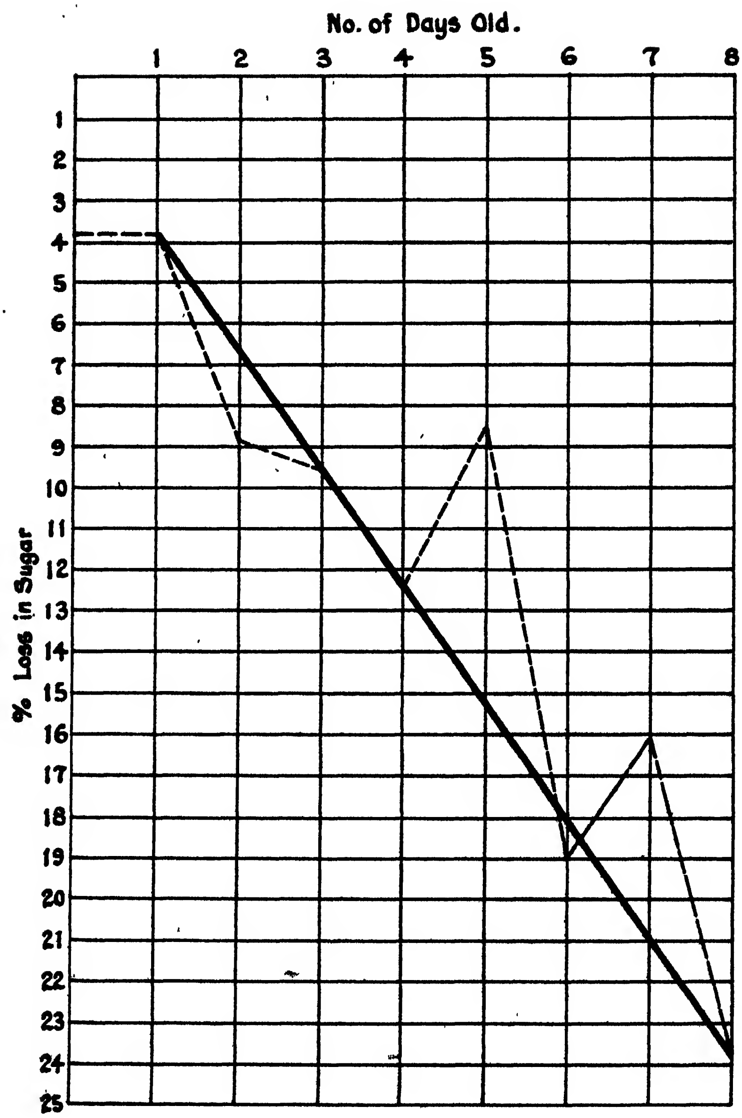

In the charts on pages 108 and 109 the per cent losses in sugar are shown graphically. The light lines show the average of the results of the different tests as actually obtained. The heavy line represents an attempt to smooth out the irregularities of the curves and represent what the true losses were from day to day.

J. A. V.

Adobe—Is Its Use Practical for Plantation Dwellings?

By Donald S. Bowman, *Industrial Service Bureau.*

The proper kind of earth for adobe construction is to be found on Oahu, Maui, Kauai, and sections of Hawaii. That adobe is a practical building material for climatic conditions similar to Honolulu is proven by the age and durability of buildings still occupied in Honolulu, such as the Damon House on Chaplain Lane, erected over eighty years ago and now used as headquarters for the Free Kindergarten Association. Adobe has been described as the building material of the ages, owing to the fact that as far back as we can go in building history we find from authentic records that the Hebrews, Syrians, Babylonians, and Egyptians had proved through long years of use its sterling worth. Adobe was formerly described as sun-dried clay, and the process of making the brick is today the same as that employed by the Egyptians—that of kneading with a binder of straw and baking in the sun. We find that it was used very extensively in Spain, and the building technique was taken to Mexico by the early Spanish settlers, where it became the chief building material, used by the rich and poor alike for the erection of homes and buildings. We find that the first adobe buildings occupied in the United States were those erected by the Pueblo Indians of Arizona. Later the early Mission Friars taught adobe brick making to the California Indians, and with their help erected the historic Missions standing today. During the reign of the Spanish and Mexican overlords in California, adobe brick made in the usual way, by hand, and sun dried, supplied the building material for their picturesque haciendas. This wonderfully cheap and adaptable material has stood the test of time. We know that not through the long ages has it been eclipsed in competition with kiln-dried brick or wood—this because of its manifest desirability, its ready adaptation into the changing architectural models of countries and periods, and, better yet, its absolute durability. Wood, which is inferior to brick or concrete, has been extensively used throughout the Islands more from habit and convenience, while adobe has not been considered owing largely to the fact that commercial firms have not been interested in its use. In California where the climate is similar to portions of the Islands, the use of adobe has been revived owing to two reasons: its easy adaptation into architects' and builders' plans is better understood than formerly; and still more important methods have been perfected for handling this material in combination with others whereby any possible objections have been eliminated. With modern methods of handling adobe construction and the scientific treatment by which it is adapted to the requirements of the twentieth century builder, we find it can be made to conform to today's wide range of structural conditions and to the demand for architectural designs of varied character. Owing to the shortage of building material in California and a growing demand on the part of some builders for the beautiful modified style of Spanish architecture, the use of adobe was welcomed as a practical necessity. That adobe construction has proven to be entirely satisfactory and practical may be seen throughout the southern part of California. At Walnut Park, where a large number of adobe houses are under construction, the builders have the following to say of their work:

"Our method of constructing these modernized adobe houses naturally is of interest to home-builders. Moreover, we are glad to give this information—based upon our actual experiences—in view of the increasing vogue of this material both for city and country dwellings.

"The initial stage of this process is the heavy concrete foundation which is put in place under all walls. This has a step for 2 x 4-inch underpinning, on the top sill of which rest the wooden floor joists. Inside, the joists are carried on beams supported by concrete piers and posts, in the usual manner of house construction. The joists are then covered with the rough sub-flooring and the interior stud partitions set up on same. The ceiling joist and rafters are then put in place and carried at the wall line by temporary struts. When built into the wall they rest on a 2 x 6-inch redwood plate mopped with asphaltum.

"The window and door frames are then set up in their proper places at the right height and, where the adobe walls are to be constructed, they are blocked up and braced in place. At each corner and angle of the house, a batter board is erected, plumbed true, and lines marked horizontally at 12-inch intervals for the guidance of the bricklayers. The top of the concrete foundation is then thoroughly mopped with a heavy coat of asphaltum waterproofing, and the job is ready for the mason work.

"The brick is laid to lines stretched from the batter boards, by common labor, under the supervision of a competent foreman. It is laid up in a clay mixture of the same consistency as the brick. Concrete lintels are cast either in place or on the ground for the openings, and a 4-inch concrete coping is cast on the parapet, where the flat roof form of construction is used. The composition roofing is carried up the parapet under this and the waterproof plastering is carried back over the joint, making a tight waterproof job. The house is then ready for the exterior plastering.

"Nails are driven into the adobe brick so that the heads project about three-eighths of an inch. A thin dash coat of cement plaster is then sprayed on the wall. This forms a key for the rough or brown coat, which is not less than 1 inch thick in any spot. The finish coat of silica sand and white hydrated cement is then put on with the character of finish specified and the whole waterproofed with a coat of transparent, standard waterproofing compound. The matter of interior wood trim is optional.

"Our adobe houses thus constructed have been found to possess advantages not obtained with any other form of construction in this climate, which is subject to a rather wide range of temperatures. The clay walls are a perfect insulation against heat and cold. No trouble arises from sweating walls. Homes of 'Modernized Adobe' are as permanent and enduring as those of brick or tile, and they cost less than half as much. Moreover, these houses are dry and warm in winter and cool and comfortable in summer when the heat rays are severe. When properly ventilated, the air in them is always sweet and clean. The heavy walls impress one with a beauty, dignity, and strength not obtainable except at great expense in any other form of construction. The interiors can always be made cosy and restful, and for comfort and health it is doubtful whether a more perfect type of home has been devised."

The adobe buildings erected throughout the southwest in the early days had no exterior finish, but were in many cases plastered within. In order to present first-hand information we wrote to a former Island man now residing in California for information in present-day adobe construction, and this is what he writes:

"Mr. John Byers, 547 Seventh Street, Santa Monica, California, is the man who is doing the biggest business in this line. I was looking for him for about a month and finally located him in Beverly Hills, the city where Burbank and his

wife reside, where he is constructing a fine Spanish style of a building of this adobe. I just jotted down a few things he gave me: Adobe bricks are 4″x 14″x 20″, and he finds with labor at about $5.00 a day that he can make them for $50.00 per one thousand, and would make that price for market. The earth about here is of the adobe kind, and all he does is to dig down where the cellar is to be and mold his brick with the straw right on the ground and let them sun bake, so that by the time he has put in the concrete foundation of from four to twelve inches from the ground and of sufficient width to bear the weight of the brick, his brick will be ready to pile. Pile is about the word, for he just seems to pile them up and the only caution seems to be to keep the house level by keeping the tiers of adobe level. He said the labor to lay 1000 of these bricks was about $100.00 if you counted the labor at $5.00 per day.

"An ordinary six or seven-room house takes 5000 bricks, so you see the expense of the construction is less than half of the price of a carpenter-made house, and the material has proven that it is less than half a tile house and one-quarter the price of lumber.

"The plastering is done quickly and the proof of the keeping properties of the house is in the old missions that have stood for hundreds of years, and many are still standing.

"Byers expects that the houses he has built will be in their places a thousand years from now unless some unusual disturbance comes to carry them away.

"These houses are warm in winter and easily heated, and are cool and dry in the summer time.

"I surely am pleased with the prospects of the thing, and now I want to get samples of the soils down there. Mr. Byers says his experts will tell us in a few minutes as to the possibility of using them in construction down there. Rain will not affect it if the coating of cement on the outside protects it, and the concrete bases keep it from the dampness of the ground and the surface water. If you will send me some samples of the soil from the several places you have thought of for building, I will take them to the expert and have his opinion upon it, and the possibilities are of a new industry in Hawaii."

From the information at hand and the success attained in adobe construction throughout the southwestern sections of the mainland, it is apparent that it would pay the plantations favorably located as to adobe soil and climatic conditions similar to Honolulu, to investigate and experiment with adobe.

Feeding Plantation Animals.*

By W. A. Wendt.†

Although at first thought it may seem that feeding is a simple proposition, if carried on properly it is a problem which requires careful consideration.

In all feeding work we must take into consideration the following points:

1. The type of animal with reference to its digestive system.
2. The purpose for which the animal is kept, e. g., meat, milk, work.
3. The feeds which are available.
4. The problem of arranging some system of feeding which will yield the most economical returns.

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* A lecture presented at the University of Hawaii, Short Course for Plantation Men, October, 1920.

† University of Hawaii.

In ruminants, ox, sheep, and goat, we find the four stomachs. The food is masticated but slightly before it passes into the first stomach. Here the mass of food lies and is partly broken down through bacterial action. It is later forced back into the mouth and remasticated, or, as we say, the animal "chews its cud." The food is then reswallowed and passes into the other stomachs to be acted upon by the digestive juices.

The bacterial action in the first stomach, together with the remastication, makes it possible for this type of animal to make use of larger quantities of coarse roughage with greater efficiency than the horse or hog, because the resistant fiber and cellulose is partially broken down into a form available as food.

The horse and hog, having only one stomach, cannot handle large quantities of roughage as efficiently as animals which chew the cud. They must therefore receive feeds adapted to their type of digestive tract.

Any substance in a feed which aids in the support of life is known as a *nutrient*. The common classes of nutrients are proteins, carbohydrates, and fats. Not all the nutrients in a feed are in an available form, hence we get the term *digestible nutrients* as applied to the portions of the nutrients which are digested and taken into the body. A ration is the amount of feed allowed an animal for one day. In order to get the most economical use out of a given ration, it is necessary that this ration be balanced, i. e., the several nutrients, protein, carbohydrates, and fat be furnished in the proper proportion.

The proportions of nutrients necessary depends on the purpose for which the animal is fed; that is, for the production of meat, milk, or work. Any animal requires a certain amount of food to maintain its body, to repair broken, wornout tissue. If we wish this animal to increase in weight, furnish milk, or do a certain amount of work, we must furnish feed which will supply nutrients enough to enable the animal to do this extra work in addition to maintaining its body.

We find that a growing animal increases rapidly in body weight in protein and mineral matter. These nutrients, therefore, must be furnished liberally in the ration of an animal maintained for meat production. Fat is also stored up in the body of a meat-producing animal and is formed largely from the carbohydrates in the food. A mature fattening animal requires very little protein, but a large amount of carbohydrates. Milk is rich in protein and minerals which must be furnished in the ration of the milk-producing animal.

The following are rules which are helpful in determining the proportions of concentrates and roughages required by various classes of animals:

1. Mature, idle horses or mature cattle can be maintained at a constant weight on a good grade of roughage alone—common hay and grass.

2. Horses at work require 1.5 lbs. concentrates (grains) and 1.5 lbs. dry roughage daily per 100 lbs. live weight.

3. Dairy cows in milk require daily 2 lbs. dry roughage per 100 lbs. live weight and 1 lb. concentrates per 3-4 lbs. milk produced.

4. Fattening steers require 1 lb. dry roughage and 1.5 lbs. concentrates daily per 100 lbs. live weight.

5. Pigs require mostly concentrates, being able to make but little use of roughage.

Horses and mules are maintained for work and must be fed a ration which supplies the necessary energy-producing nutrients. Experiment has shown that the carbohydrates and fats of the food are first drawn on as sources of muscular work.

The source of the carbohydrates will be the concentrates in the ration. On plantations, perhaps, the most economical carbonaceous concentrate is molasses. This may be poured on the roughage or mixed with the grain. Some grain, oats, barley, or bean meal should make up part of the concentrate ration. Although oats is the ideal grain for horses, a long series of tests has shown that barley is equal to oats as a feed.

The roughage may consist chiefly of cane tops, although if clover or alfalfa hay is fed, not over 1.2 lbs. per 100 lbs. live weight, the amount of grain supplied may be cut down considerably. A definite allowance of roughage should be fed to prevent the horse overeating and becoming subject to digestive disorders. Mules will not overeat. The larger portion of the ration should be fed at night, thus allowing plenty of time for mastication and digestion. Feed one-fourth in the morning, one-fourth at noon, and the remainder at night.

The following table would be very useful in balancing the ration for plantation animals:

AVERAGE DIGESTIBLE NUTRIENTS IN FEEDING STUFFS.

Name of Feed	Total dry matter in 100 lbs.	DIGESTIBLE NUTRIENTS		
		Crude Protein	Carbo-hydrates	Fat
Sugar Plantation Products	lbs.	lbs.	lbs.	lbs.
Cane top hay (estimated).....	63.2	2.0	38.0	1.2
Cane tops, green (estimated)..	15.8	0.5	9.5	0.3
Molasses.....................	74.1	1.4	59.2	0.0
Hawaiian Grown Feeds				
Dried roughages—				
Peanut vine hay	92.4	6.7	42.2	3.0
Para grass (dry)	...	5.5	45.6	0.6
Alfalfa hay	91.9	10.5	40.5	0.9
Green roughages—				
Alfalfa	28.2	3.6	12.1	0.4
Cowpea vines	16.4	1.8	8.7	0.2
Bermuda grass	28.3	1.3	13.4	0.4
Root crops—				
Cassava	34.0	0.8	28.9	0.2
Sweet potato	28.9	0.8	22.9	0.3
Concentrates—				
Rice Bran	90.3	7.6	38.8	7.3
Corn	89.4	7.8	66.8	4.3
Algaroba meal (total nutri).	...	9.8	55.2	1.2
Imported Feedstuffs				
Barley	89.2	8.4	65.3	1.6
Wheat bran	88.0	11.9	43.1	3.1
Oats	89.6	8.8	49.2	4.3
Cottonseed meal	93.0	37.6	21.4	9.6
Cocoa meal	89.7	15.4	41.2	10.7
Tankage	93.0	50.1	0.0	11.6

FOOD REQUIREMENTS OF DIFFERENT ANIMALS PER DAY PER 1000 LBS. WEIGHT.

	Dry matter	Crude Protein	Carbo-hydrates	Fat	Nutritive ratio
Horses and Mules	lbs.	lbs.	lbs.	lbs.	
Light work......	20.0	1.5	9.5	0.4	1—7.0
Medium work.....	24.0	2.0	11.0	0.6	1—6.2
Heavy work.....	26.0	2.5	13.3	0.8	1—6.0
Fattening Cattle					
First period......	30.0	2.5	15.0	0.5	1—6.5
Second period...	30.0	3.0	14.5	0.7	1—5.4
Third period....	26.0	2.7	15.5	0.7	1—6.2
Milk Cow					
11.0 milk daily...	25.0	1.6	10.0	0.3	1—6.7
22.0 " " ..	29.0	2.5	13.0	0.5	1—5.7
27.5 " " ..	32.0	3.3	13.0	0.8	1—4.5
Brood Sow........	22.0	2.5	15.5	0.4	1—6.6
Fattening Swine					
First period.....	36.0	4.5	25.0	0.7	1—5.9
Second period...	32.0	4.0	24.0	0.5	1—6.3
Third period....	25.0	2.7	18.0	0.4	1—7.0

PLANTATION STOCK FOODS PREPARED BY THE HAWAIIAN COMMERCIAL AND SUGAR COMPANY.

SUGAR BRAN—"MULES DELIGHT"

Dried brewer's grains	10.5%
Algaroba bean meal	35.0%
Alfalfa meal	13.2%
Dried cane bagasse	6.3%
Cane molasses	35.0%

CONTAINS

Dry matters	86.7%
Digestible protein	7.5%
Nutritive ratio 1—6.9	
Home grown constituents	89.5%
H. C. & S. Co. cost—$20 per ton.*	

SUGAR BRAN—"DAIRY FEED"

Cocoanut meal	6.8%
Dried brewer's grains	6.8%
Algaroba bean meal	33.8%
Alfalfa meal	12.7%
Dried cane bagasse	6.1%
Cane molasses	33.8%

CONTAINS

Dry matter	86.8%
Digestible protein	7.8%
Nutritive ratio 1—6.7	
Home grown constituents	86.4%
H. C. & S. Co. cost—$21 per ton.*	

SUGAR BRAN—"HOG FEED"

Blood meal	3.8%
Cocoanut meal	3.8%
Algaroba meal	37.5%
Alfalfa meal	14.0%
Dried cane bagasse	3.4%
Cane molasses	37.5%

CONTAINS

Dry matter	86.2%
Digestible protein	9.0%
Nutritive ratio—1-5.9.	
Home grown constituents	92.4%
H. C. & S. Co. cost—$21.25 per ton.*	

(Tables and data given above secured from "Feeds and Feeding" by Henry, and from the Hawaiian Planters' Record.)

* Old prices.

Testing Welds.*

By S. W. Miller, M. E.

The question of testing welds is one that has been considered more or less since welding was known, but especially during the last five years. Its importance has now become very great. There have been many failures in the past, many of them not having been explained and some of them having been very expensive. As in all other developments, welding first received its principal impetus from the practical man. Of late, however, the tendency has been to investigate more carefully and more fully and by means not available to the ordinary welder. This means that scientists of all kinds have been called into consultation and that almost every conceivable method of test has been suggested in order to determine what methods and materials would make the best welds from a standpoint of security, service and cost.

The welding of steel is frequently considered as not being especially difficult, and it is also sometimes considered that steel is steel and that no different treatment is required in the case of different qualities and varieties of steel. This idea is much less common today than it was several years ago, but it is still too prevalent for the good of the art. It is not well known as it should be that a comparatively small difference in the percentage of carbon in the material being welded makes a very great difference in the results of either a bend or tensile test. If the carbon is 0.12 per cent or less, the material is soft, ductile and yields readily to any strain that may be put on it. Such material is frequently used for tanks and, because of its ductility and comparative freedom from damage by heating, is admirably suited for welding. Structural steel, bar steel and boiler plate contain about 0.15 per cent to 0.25 per cent carbon and have a tensile strength of about 60,000 lb., while the soft low-carbon material has only about 52,000 to 55,000. Ship plate is required to have a tensile strength of from 58,000 to 68,000 lb. and in the heavier sections requires as high as 0.30 per cent carbon. It has been found by experience that the higher the carbon, the more difficult it is to get a satisfactory weld and the more danger there is of injuring the metal being welded. It is also evident that a weld made with a given welding rod or electrode can have only a given strength. If this strength is greater than that of the material being welded, the test piece will always break outside of the weld. If, on the other hand, the weld is weaker than the material being welded, the rupture will always take place in the weld. An oxyacetylene weld made with ordinary low-carbon welding wire will have a tensile strength of about 52,000 lb. This is stronger than soft tank steel and weaker than the other materials mentioned. It is possible to get with alloy steel rods of proper composition a tensile strength in an oxyacetylene weld of about 50,000 lb. Neither of these materials will weld boiler steel, boiler plate or ship plate, so

* **Abstract from a paper read before the September meeting of the Chicago Section of the American Welding Society.**

that the rupture will occur outside the weld when the section of the weld is the same as the section of the piece, and in making tests of welded pieces, it is necessary to know accurately the character of the material being welded.

The method of test to be applied in any given case depends largely on the use to which the welded piece is to be put. If it is to be used in a pressure vessel, I believe that not only should a tensile test be made, but that an alternating stress test should be used because of the breathing of the tank due to changes of pressure. This latter test should also be applied where the weld is subjected to bending strain. There are no standards at present for weld tests, but it is advisable, wherever possible, to follow those of the A. S. T. M.

The best test, in my opinion, to determine quickly the general character of a weld, is to grind it off level with the surface of the pieces and clamp it on an anvil, with the center of the weld level with the top of the anvil, the bottom of the "V" toward the anvil so that the top of the weld is stretched when the projecting end is struck with a sledge. The blow should not be too heavy, and the number of blows and angle to which the piece bends before cracking are quite a good index of the value of the weld. It is true in this test, as in the tensile tests, that the quality of the material being welded has a great influence on the results. Stiff material throws more of the strain into the weld, while soft ductile material will itself take considerable of the bend. In the case of defective welds—that is, those not fused along the "V" or which contain slag or other inclusions—this test will at once develop the defects. If a welded piece were to be used in a place where it might became red hot such as, for instance, in a locomotive firebox crown sheet, it would be entirely proper to test the welds at a good red heat by clamping them in a heavy vise or on an anvil with the center of the weld about half an inch from the edge of the vise or above the face of the anvil, heating them to a bright orange with the torch and then bending them as before as with a sledge.

If such welds are made in a ½ x 2-inch bar steel, a 90-degree single "V" being used, and they bend to a right angle cold without cracking on the outside, a welder may feel well satisfied with his work.

Testing Rails for Hidden Defects.

There has recently been developed a method for testing rails for hidden defects which was devised by A. M. Waring. It consists of deeply etching a polished surface of the material under test. For instance, a section of a weld might be cut out with a hacksaw, machined or filed to a true surface, and polished on various grades of emery paper, ending up with 00 Manning. It is then placed in a warm solution of 25 per cent hydrochloric acid and water for from one-half to an hour. The acid will eat away the defects, making the edges of the material at them taper, so that rather large grooves and pits will be visible where the defects prior to the etching would be only microscopic. The etching test I consider to be of the greatest value in ordinary shop practice where it is desired to find out rapidly and quite accurately the quality of the work done by the different welders.

These rough tests, while satisfactory for determining the general quality of the work, do not answer as a basis for design, and more refined tests must be used

as before referred to. I believe that the most important of these are the tensile and alternating-stress tests. The tensile test can be made in any shop provided with the usual tensile testing machine. The alternating-stress test is not as yet standardized even for unwelded material. I am inclined to believe that the machine devised by the Quasi-Arc Company is of considerable value, although it does not give absolute results; that is, it does not give the amount of fiber stress to which the piece is subjected.

A great deal may be learned from the appearance of a weld. It is difficult to describe the appearance of good welds, but after they have been seen a number of times, an inspector can readily say whether the operator knows what he is doing. In gas welding, I would not accept a ripple weld in heavy material nor one which was narrower than about 2½ times the thickness of the sheet, because I have never seen a weld having these appearances that was properly made. The appearance in a gas weld of porosities on top indicates that the metal has been overheated, and the same thing is true in an electric weld. Inasmuch as I believe that the serious defects in welds are caused by oxides, it would appear wise in the case of gas welding to use no larger top than is necessary to produce thorough fusion. This means that the catalogue speeds of welding are impossible if good welds are desired. The same thing is true of electric welds. The reason is that at the high temperatures of the steel caused by too large a tip or too heavy a current, the metal becomes overheated, and in that condition combines more readily with the oxygen of the air or with any excess oxygen in the torch flame, and produces oxides which are readily dissolved by the melted metal. As the metal cools down, these oxides are rejected in large part and pass to the grain boundaries, as do other impurities, so that it is perfectly natural that material that has been seriously overheated should be more brittle and weaker than the material that has been properly melted. In conclusion, I have found in a number of cases that very great improvements in the quality of the work were made by using regularly the bending test already described and by carefully instructing the welders until they were able to make welds that would meet this test with unfailing regularity.

A New Method of Rat Repression.*

Applying a Sex Law.

Mr. George Jennison, of Belle Vue, reading a paper before the Conference of Rat Officers at the Royal Sanitary Congress at Birmingham yesterday, said that noxious rats appeared in France about 1755 in the neighborhood of the great menageries of Versailles, Chantilly, and Marly la Ville, and had probably been imported as curiosities from India. According to Buffon, they multiplied prodigiously and did great damage. That their ravages were as great in England is proved by the vogue of Robert Smith's "Complete Rat-Catcher," a three-

* From an English paper.

page pamphlet that sold for a guinea. His method still held—destruction by dogs and infallible baits,—but, in spite of continual persecution both from necessity and as a cheap and popular sport, the rat held its own or increased everywhere, from two reasons. First, living near man protected it from all natural enemies; secondly, its great fecundity mocked all efforts for its annihilation.

"Boulter," he said, "estimated the rats as equal to the human population and their annual cost at £15,000,000 (it would now be £40,000,000). He stated the potential increase of one female in a year as 880, but that was grossly below the mark, as he took his average litter as four males and four females, whereas the proportion is four to six, and the potentiality therefore about 1350. Taking only one-sixth of this figure, the females alone would increase 130-fold annually, which means that ten females might leave 170,000 females, besides 120,000 males, in two years." So there were evidently other checks. Food scarcity was the chief; rationing had resulted in great catches of females. The other great check was struggles amongst the rats themselves, and particularly the harrying of the breeding females. It was precisely on these two points that men helped the rat to survive—the more killed, the more food for the remainder, and as the males are bolder than the females and are caught therefore in disproportionate numbers, not only was breeding made easier, but the rat became more polygamous and the evil was thereby increased.

Mr. Jennison advocated catching the rats alive; killing the females and releasing the males. The idea, he said, was given to him by Mr. Isaac Bailey, formerly gamekeeper at Swythamley Hall, Macclesfield. Later he found it had been used by Mr. William Rodier, of 327 Collins street, Melbourne, who claimed to have cleared 64,000 acres of a rabbit-infested district in 20 years by this means alone, whereas poisoning, which is obligatory in Australia, had been and is a failure. The lecturer said that on this evidence he had changed his own destructive methods for the new system with marked results, and submitted the following table of results at Belle Vue:

	Trappings	Males	Females	Total	Average per Month
1915—Oct, 11-Dec. 31.	8	40	45	85	34.6
1916—January-June.	12	96	82	178	30
July-December	11	50	92	142	24
1917—January-June.	14	60	84	144	24
July-December	12	72	135	207	* 34.5
1918—January-June.	12	35	104	139	23
July-December	12	41	64	105	17.5
1919—January-June.	13	40	68	108	18
July-December	13	55	50	105	17.5
1920—January-June.	13	52	59	111	18.5

* Caused by rationing and food scarcity.

Under his system the reduction was gradual and the results little affected by food, which had been quite normal since the Armistice, and males were now being caught in larger proportions, which showed that the balance of sexes was being disturbed in the right direction.

Summarized, the matter stood thus:—Rats are to be exterminated; they do, say, 30 millions of damage annually; they cannot all be killed—killing many has little value; easier feeding means quicker breeding; a small neglect means a swarm renewed; the disposal of dead rats is a serious sanitary problem; the Rodier method—killing females only—is slower and more difficult, but it is efficacious in plenty or scarcity—it allows for long periods of neglect, it works in Nature's way; you can only conquer Nature by obeying her.

Mr. Jennison asked the conference not to reject the idea because it was new and strange—there was really nothing novel about it; every one of them who bred horses, dogs, sheep, poultry, pheasants or pigeons knew that an excess of males meant failure, and regulated the supply accordingly. They were unwittingly doing the same with rats and getting the same results, whereas they wanted the contrary to happen. He also drew attention to two cases where the sex law had been unwittingly applied to wild creatures. First, the male bird of paradise, never very numerous as a species, had been hunted for plumes for two thousand years: result, the race became polygamous and still survives. Secondly, the passenger pigeon, counted by the thousands of millions only a century ago, was hunted at nesting-time, when the female sits for 20 hours in the day, consequently they were killed in excessive numbers: result, the race was exterminated in 60 years.

The lecturer also submitted a table of the captures in Copenhagen, where there was a very efficient rat law. He noted that in the first year under this law an enormous proportion of rats was killed—the figures were 312,949,—but that for seven years afterwards all the Danish effort produced no effect whatever; the subsequent reduction was due to the war and food scarcity. As food supplies increased and buildings were likely to deteriorate the captures in that city would, he predicted, reach 150,000 shortly.

[J. N. S. W.]

Air-Pump Capacities and Incondensible Gas Volumes in Industrial Vacuum-Evaporator Plant.*

By Edward Corner.

The rather unfortunate general use of empirical formulæ for the determination of air-pump capacities in evaporator work has led the writer to attempt to lay down in a clear and concise manner the theoretical principles entailed, with practical data and a set of curves, which will enable designers to choose the correct value for any particular case.

Empirical formulæ are undoubtedly most useful in average cases, and under satisfactory conditions designs obtained by their use are good enough for practical purposes, but many cases have occurred in which a fuller knowledge of the root principles would have been of extreme value to the designer, and would undoubtedly have enabled him to produce a more efficient and satisfactory apparatus. It is often remarked by draughtsmen and engineers, who have been con-

* Reproduced from Engineering, 1920, CIX., No. 2820.

nected with more than one firm, how great the variation is between the empirical figure taken in one shop and that taken in another, and the writer is personally acquainted with three different values for the capacity of dry-air pumps, values which differ so greatly that it is difficult to explain the fact that these firms are all makers of very satisfactory plants.

Now, empirical formulæ, especially as regards condensation problems, can only be considered accurate or practically accurate between certain limits, i. e., a single value for, say, air-pump capacity cannot be expected to cover all variations of injection temperature, vacuum, or hot-well temperature, and it is essential that in many cases an accurate factor should be obtained, applicable to the particular conditions prevailing.

The possible vacuum in any condenser is directly due to the absolute pressure in the condenser, this absolute pressure being the sum of the partial pressure of water-vapor and air or other incondensible gases present.

According to Dalton's Law, any number of gases enclosed in a vessel will each exert a pressure upon the walls of the vessel equal to the pressure such gas would have exerted had it been present alone, and the total pressure in the vessel is the sum of the partial pressures of all the gases present. Also, each gas occupies the whole space, or, in other words, the molecules of the different gases are intimately mixed.

The temperature prevailing in a condenser is, approximately, that of the outgoing or "tail" water, and it is easily seen that this temperature is the governing factor in fixing the vacuum. It is sometimes thought that the quantity of air relative to steam, entering the condenser, plays an important part in determining the vacuum, but as the ratio of air to steam is always very small, the actual effect can safely be neglected and, in fact, has no influence whatever in the latter part of the condensation, i. e., after the latest heat has been removed. Immediately after condensation of the steam, the ratio of air to vapor becomes very greatly increased, and the partial pressure of the air becomes a very important factor in determining the vacuum, and it is this partial pressure of the air which explains the difference between the vacuum shown on the gauge and the vacuum which one would expect from the relative thermometer reading.

The volume of 1 lb. of air enclosed in a space, at any temperature and pressure, is found as follows:

$$V_2 = \frac{V_1 P_1 (T_2 + 460)}{P_2 (T_1 + 460)}$$

where V_1 = volume of air in cubic ft. per lb., at 60° F., and 14.7 lbs. per sq. in. = 13.1 cu. ft.

V_2 = volume as above, at P_2 and T_2.

P_1 = 14.7 lbs. per sq. in.

P_2 = Pressure of air at T_2 and volume required.

T_2 = 60° F.

Substituting the given values in the above formula, we get:—

$$V_2 = \frac{13.1 \times 14.7 \times (T_2 + 460)}{P_2 \times 520} = \frac{0.37 (T_2 + 460)}{P_2}$$

In a mixture of steam and air, at any given volume and temperature, the volume of the air is equal to the volume of the steam, and also equal to the total volume, and its weight is:—

$$W = \frac{p_2 \times V}{0.37 \times (T_2 + 460)}$$

where W = weight in lbs. of the air contained in the mixed volume.
P_2 = pressure of the air, which is equal to the total pressure minus the pressure of the water vapor or steam at temperature T_2.

Fig. 1. WET-AIR PUMPS JET CONDENSERS.

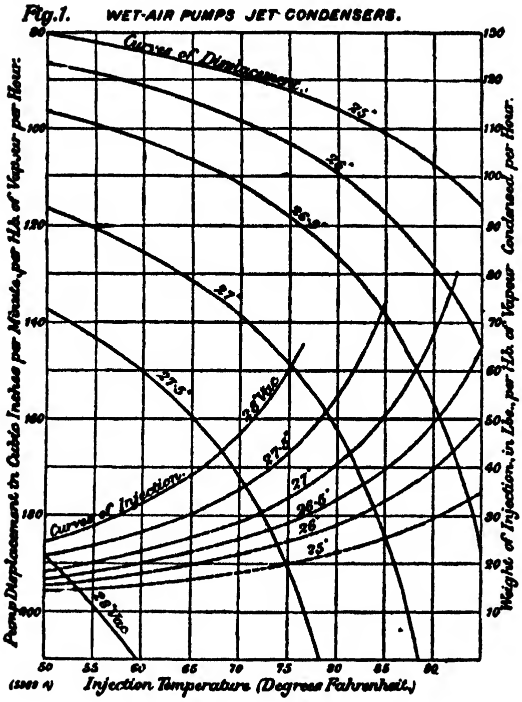
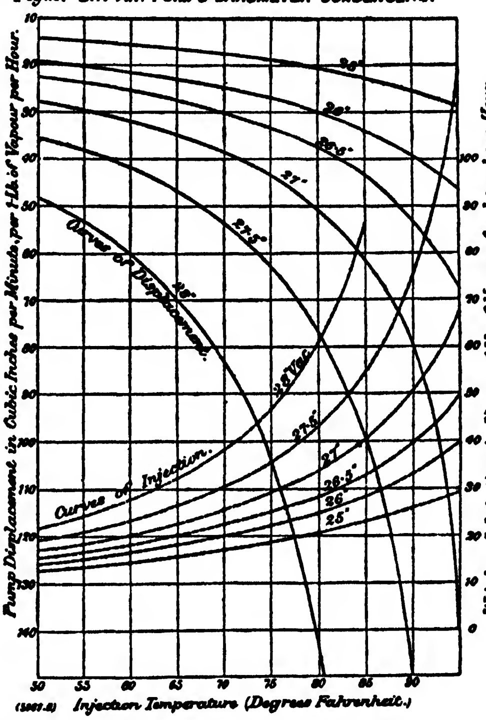


Fig. 2. DRY AIR PUMPS BAROMETER CONDENSERS.



The usual allowances or data for ratio of air to steam, which are applicable to power plants, are very much too low for industrial evaporator work, as this latter plant exposes a much greater joint surface, and is working with liquors which contain a large quantity of gases in solution, as well as other gases which are evolved during the evaporation process. On the other hand, the water used for injection is very often at a much higher temperature than that used in European plant, and thus contains slightly less air; this, of course, is only intended to apply to tropical conditions, and chemical evaporators working in Europe would, naturally, have conditions of injections similar to power-plant in the same locality.

The most reliable figures for incondensible gas volume relative to steam entering the condenser are as follows:

(1) 4 lb. of air per 1000 lbs. of steam or vapor.
(2) 0.2 lb. of air per 1000 lbs. of liquor treated.
(3) 0.1 lb. of air per 1000 lbs. of injection water.

These values are originally intended for sugar-juice evaporators, but can be used with confidence for almost all chemical liquors, and for any temperature of

injection. The quantity, under heading (2) above, varies with the number of vessels in the evaporator, and a table of constants is given for the various groupings, as the curves are all calculated for the most usual triple-effect grouping; a set of multipliers is also appended, to facilitate calculation.

As previously mentioned, the possible vacuum in any condenser is directly due to the temperature of the "tail" water, and in condensers of the jet type this tail water is the condensed steam, together with the injection water. The formulæ for obtaining air-pump capacity for any type of jet condenser are very similar, only differing in respect of the values taken for the temperature at which the air is withdrawn, and in the case of barometric or counter-current jet condensers, the pump is not required to deal with any tail water, and thus no factor for this is embodied.

Now, as stated above, the most important factor in determining the possible vacuum is the temperature of the tail water, and indirectly this temperature greatly affects the volume of air which must be withdrawn. Every pound of injection water brings with it a certain quantity of air, and thus the greater the quantity of injection water used the greater the quantity of air which must be removed. Against this, must be placed the fact that, the greater the quantity of injection water used, the lower will be the temperature of the tail water, and consequently a higher vacuum will be obtained, together with a lower air temperature and smaller volume per pound. A set of curves plotted for this purpose shows a marked diminution of air-pump volume, with increase of injection water ratio up to a certain limit, after which pump capacity rises rapidly, on still further increasing this ratio.

To find the ratio $\frac{\text{injection water}}{\text{steam}}$ by weight, the following simple formula is used:

$$W = \frac{L + (T_1 - T_2)}{T_2 - T_3}$$

where W = weight of injection water per pound of steam per hour.
L = Latent heat of the steam at temperature due to required vacuum. or T_1.
T_1 = Temperature of steam at the required vacuum.
T_2 = Temperature of the "tail" water.
T_3 = Temperature of the injection.

It is usual to assume T_3, 10° below T_1 for low-level, parallel-flow jet condensers, and 5° below T_1 for barometric or other counter-current jet condensers. These allowances are considered sufficient in most cases, but the designer must satisfy himself, in special cases, that the temperature difference given by these values is sufficient for the complete transmission of the heat during the passage of the steam through the condenser, or, in other words, that the condenser is of sufficient length. The curves in Figs. 1 and 2 are plotted for conditions as given above; other conditions will, of course, require special calculations, of which formulæ are given below in their respective places.

Low-level parallel-flow condensers. The air which is to be removed from this type of condenser is withdrawn along with the tail water, and is, therefore, practically at the same temperature, and its volume may be calculated as follows:

$$V_2 = \frac{V_1 P_1 (T_2 + 460)}{P_2 (T_4 + 460)}$$

where V_2 = volume of the air, in cu. ft., per lb. at temperature T_2.
P_1 = 14.7 lbs. per sq. in. pressure.
P_2 = Pressure of the air, or difference between total pressure in the condenser and the pressure of water-vapor at temperature T_2.
V_1 = 13.1 cu. ft.
T_2 = temperature of the tail water.
T_4 = 60° F.

This formula, as already shown, becomes on substitution:—

$$V_2 = \frac{0.37 (T_2 + 460)}{P_2}$$

The pressures used in condenser work being all below atmospheric pressure, and as temperature is such an important factor, it is found more convenient to take these pressures in inches of mercury rather than in pounds per sq. in., and the above formula then becomes transformed to:—

$$V_2 = \frac{0.37 (T_2 + 460) \times 2.04}{p_2} = \frac{0.755 (T_2 + 460)}{p_2}$$

The formula given above enables one to calculate the volume of 1 lb. of air at any temperature or pressure, but in order to obtain the pump displacement, it will be necessary to revise the above so as to give the volume of air and tail water per pound of steam, and as pump displacement is usually given as cubic inches per minute per 1 lb. of steam condensed per hour, a further alteration should be made in its construction.

$$D = \frac{0.755 (t + 460) \times (k + m) \times 1728}{P_2 \times 60} + n.$$

$$= \frac{21.8 (t + 460) \times (k + m)}{p_2} + n.$$

where D = Pump displacement, in cubic inches per minute per 1 lb. of steam condensed per hour.
t = temperature of tail water in deg. F.
P_2 = Pressure of the air (see above).
k = a constant, for type of apparatus. See Table 1.
$m = W \times 0.0001$ or $\dfrac{\text{lbs. of injection} \times 0.0001}{\text{lbs. of steam}}$
$n = (W + 1) \times 0.462$ = volume of tail-water.
W = weight of injection in pounds per 1 lb. of steam condensed per hour.

The curves given in Fig. 1 are plotted from this formula, tail water being taken at 10° below temperature proper to vacuum; injection water quantities are also given in the dotted curves. The values obtained from these curves are, of course, minimum values, and should be increased according to the designer's experience, and for the particular type of pump employed; for those unused to this type of work, the writer suggests an increase of 10 per cent as being quite sufficient to meet all contingencies.

Barometric condensers, or low-level counter-current apparatus. In this type the air is withdrawn at a point, either above or very little below the injection-water inlet, and is therefore removed at, or almost at, the temperature of the injection. The air pump deals with air only, and as this air is cooler, and therefore denser, the pump is necessarily smaller than the wet type of similar condensing capacity.

The formula giving injection water quantity is similar to that given previously, excepting that the temperature of the tail water is taken 5° below temperature proper to vacuum.

The temperature of the air is taken here as being 2° above that of the injection water, and this has been added to the absolute temperature value in the formula:

$$D = \frac{0.755\ (t + 462) \times (k + m) \times 1728}{P_2 \times 60}$$

$$= \frac{21.8\ (t + 462) \times (k + m)}{P_2}$$

where the symbols have the same meaning as in the previous formula, except t, which in this case is the temperature of the injection water.

The curves given in Fig. 2 are plotted from the above formula, and, as before, are, of course, minimum values. It will be noticed that a vacuum of 28 in. or over requires very large pump capacity, when the injection exceeds 70° F., and as this temperature is generally lower than the usual for tropical countries, it is very rare to find apparatus designed for such high vacua when intended for such localities.

In actual practice, a small portion of the air is carried out in the tail water, but it is safer, as a rule, to neglect this quantity.

Surface condensers. For this type of condenser very different conditions exist; the steam is condensed without coming into actual contact with the injection or circulating water, and the quantity of air to be dealt with is correspondingly reduced.

Most surface condensers are designed for counter flow, as this enables the circulating water to be used to the greatest advantage, and also allows the lowest possible temperature of the condensate being obtained.

There is a great deal in the design of surface condenser plant which depends upon special conditions, and as this is beyond the scope of the present article, the writer offers the curves in Fig. 3 as being only a guide, as it is almost impossible to give values which would suit all conditions.

The curves given are calculated on the assumption that the injection water is raised to a temperature 5° below that due to the vacuum, and that the condensate is cooled to 5° above the injection or circulating-water-inlet temperature.

$$V = \frac{21.8\ (t + 460) \times k}{P_2} + n_2$$

where V = displacement of vacuum pump in cubic inches per minute per 1 lb. of steam condensed per hour.

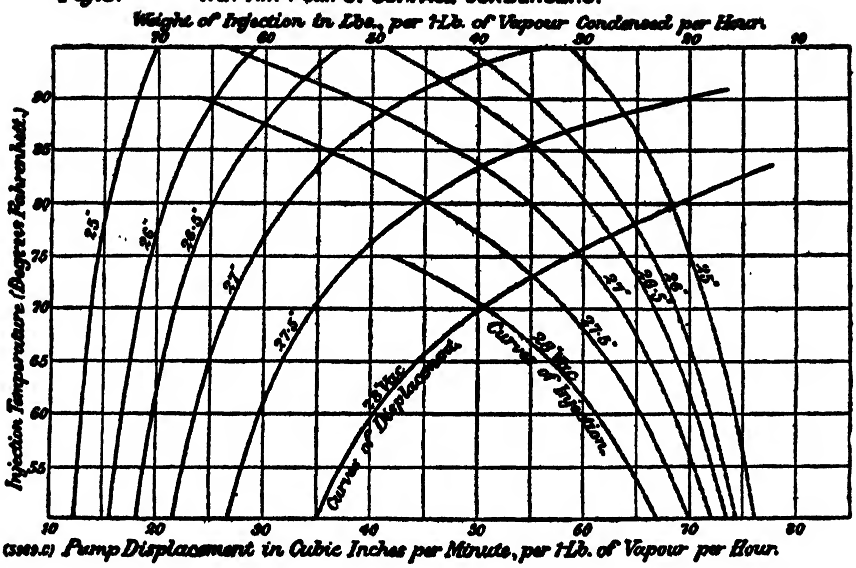
P_2 = pressure of the air (see above).

k = a constant, see Table 1.

n_2 = volume in cubic inches per minute of 1 lb. of condensed steam = 0.462.

t = injection temperature + 5°.

Fig. 3. WET-AIR PUMPS. SURFACE-CONDENSERS.



In the curves, *k* has been taken as 0.0048, which is the value for triple-effect evaporators, and the displacements given by these curves must be multiplied by the co-efficients given in Table 2, if any other grouping of apparatus is required.

TABLE 1.—VALUES OF "K" $= \frac{\text{AIR}}{\text{STEAM}}$ IN POUNDS PER HOUR.

Type of apparatus.	"k"
Single effect	0.0044
Double effect	0.0046
Triple effect	0.0048
Quadruple effect	0.0059
Quintuple effect	0.0062

TABLE 2.—CO-EFFICIENTS FOR CORRECTING DISPLACEMENT GIVEN IN CURVES, FOR GROUPINGS OTHER THAN TRIPLE EFFECT.

Type of apparatus.	Co-efficient.
Single effect	0.917
Double effect	0.958
Triple effect	1.000
Quadruple effect	1.23
Quintuple effect	1.29

The word "air" used in many places throughout the text is intended to cover all incondensible gases.

The writer has not intended to give a thorough scientific reasoning, nor to make allowances for all the minute phenomena connected with this subject; such scientific, or, one should say, academic treatment is certainly desirable in dealing with research work, or in training students, but the errors caused by the omission of these refinements in the formula are so small as to be negligible, and as the points for the curves were all obtained by slide-rule aid, such differences have no doubt been fully covered by the method of taking the next higher even figure.

[W. R. M.]

SUGAR PRICES*

Ended February 15, 1921.

	96° Centrifugals		Beets	
	Per Lb.	Per Ton.	Per Lb.	Per Ton.
Feb. 2, 1921	4.485¢	$ 89.70		
" 3	4.51	90.20	No quotation.	
" 4	4.64	92.80		
" 8	4.89	97.80		
" 10	5.015	100.30		
" 11	5.2867	105.734		
" 14	6.02	120.40		
" 15	5.765	115.30		

* In order to fit in with our time of going to press, the sugar prices are here given for the first half of February. Hereafter, the period covered will be from the middle of one month to the middle of the next.

[D. A. M.]

THE HAWAIIAN PLANTERS' RECORD

Volume XXIV. APRIL, 1921 Number 4

A monthly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

H. S. P. A. Committees.

The Secretary of the Association informs us that the following are the committees thus far appointed by the President, Mr. E. Faxon Bishop:

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Cutting Back Versus Not Cutting Back.

Oahu Sugar Company Experiment No. 12 (1920 Crop).*

SUMMARY.

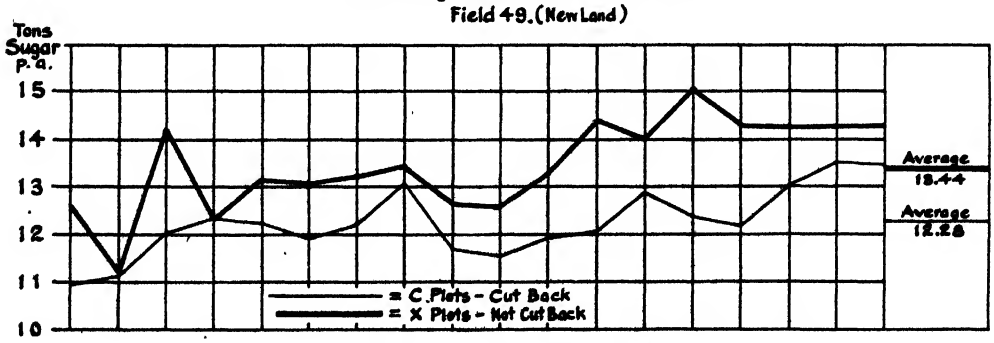
This experiment compares the practice of cutting back against not cutting back of D 1135 at an elevation of 550 to 600 feet. As originally laid out, this experiment involved both Lahaina and D 1135, but because of the ravages of Lahaina disease on the Lahaina, only the D 1135 area was harvested.

The results are decidedly against cutting back. This operation caused a decreased yield of 7.45 tons cane or 1.16 tons sugar. The following tabulation shows the actual yields obtained:

Plot	No. Plots	Treatment	Yields in Tons per Acre	
			Cane	Sugar
C	18	Cut back	89.61	12.28
X	18	Not cut back	97.06	13.44

The previous crop was harvested the first week in May, 1918, and from then until July 7, 1918, the field received no fertilizer, but sufficient water to keep it growing. Cutting back took place on the latter date, when the cane was from 12 to 18 inches high. All plots were given uniform fertilization, consisting of two applications of 400 pounds each of complete fertilizer and two doses of 262.5 pounds each of nitrogen mixture. In the first week of January, 1919, after tasseling was complete, a count was made of the tasseled and untasseled sticks in the

CURVE SHOWING THE YIELD IN SUGAR PER ACRE FOR EACH PLOT, CUT BACK & NOT CUT BACK.
Oahu Sugar Co. Exp. 12, 1920 crop
Field 49. (New Land)



middle row of each plot. In the case of D 1135 there were no tassels in either the cut-back or the not-cut-back portions, while in the case of Lahaina there were no tassels in the cut-back portion, but in the not-cut-back portion 16% of the stalks had tasseled.

* Experiment planned by J. A. Verret.

The treatment seems to have made no difference in the quality of the juices, as is shown by the following tabulation:

Treatment	Brix	Pol.	Pur.	Q. R.
Cut back	22.66	18.73	82.66	7.30
Not cut back	22.36	18.78	83.99	7.22

DETAILS OF EXPERIMENT.

Object: To determine the value of cutting back versus not cutting back for fields at an elevation of 600 feet.

Location: Oahu Sugar Company, Field 49, Hoaeae Section, Section 2, Divisions 6 to 14, inclusive, of experimental area of this field.

Crop: Lahaina and D 1135 in plots and D 1135 in crop areas, first ratoons, long.

Layout: No. of plots, 36.

Size of plots, 1/20 acre each (39.6′x 55′), consisting of 10 single rows 5.5′ wide and 39.6′ long. Each plot one water-course in width. Each single row 1/200 acre. These areas include water-courses.

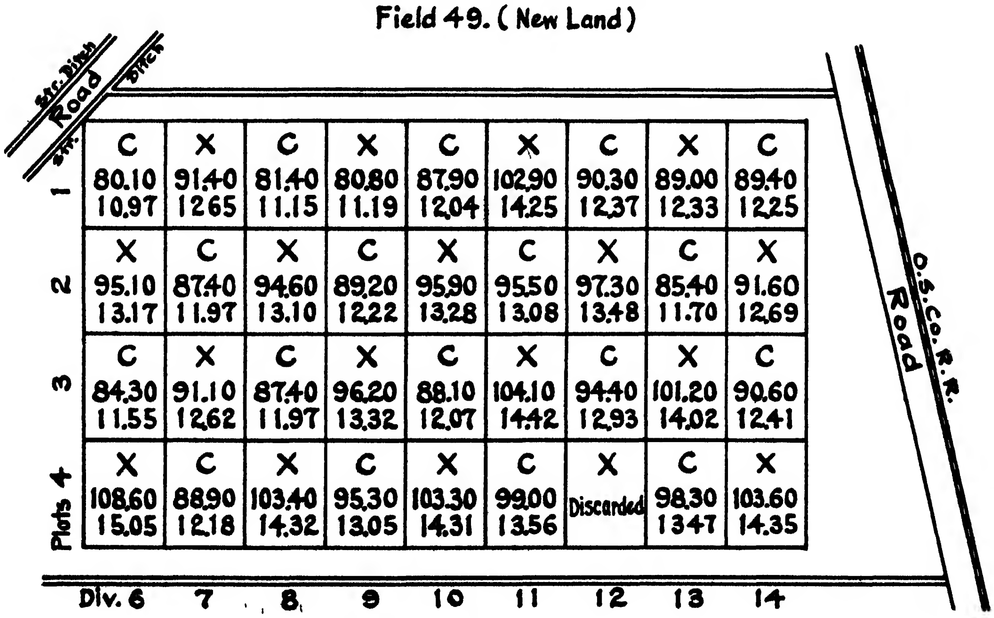
Plan: All C plots (which were EE, DD, or CC plots for the 1918 crop) are to be cut back, and all X plots are not to be cut back.

Fertilization uniform to all plots and crop cane as follows:

August, 1918—400 pounds per acre of C. F.

October-November, 1918—262.5 pounds per acre of N. M.

CUT BACK VS. NOT CUT BACK
Oahu Sugar Co. Exp. 12, 1920 Crop
Field 49. (New Land)



Summary of Results

Plots	No. of Plots	Treatment	Yields Per Acre			Gain or Loss Over Cut Back Plots.	
			Cane	Q.R.	Sugar	Cane	Sugar
C	18	Cut Back	89.61	7.30	12.28		
X	18	Not Cut Back	97.06	7.22	13.44	+ 7.45	+ 1.16

February-March, 1919—400 pounds per acre of C. F.
May-June, 1919—262.5 pounds per acre of N. M.
C. F. = complete fertilizer: 10% N. (7% sulfate, 3% nitrate), 8% P_2O_5, 1% K_2O.
N. M. = 18% N. mixture (½ nitrate, ½ sulfate).

PROGRESS OF WORK.

July 7, 1918—Cut back.
August 26, 1918—First fertilization.
November 4, 1918—Second fertilization.
January 3-5, 1919—Tassels counted.
February 21, 1919—Third fertilization.
June 6, 1919—Fourth fertilization.
August 9-13, 1920—Experiment harvested by Y. Kutsunai.
Juices sampled in carload lots at mill by R. Pahau.

R. S. T.

The Laborer's Teeth.

BAD TEETH CAUSE OF LESSENED PRODUCTION.

By Donald S. Bowman, *Industrial Service Bureau, H. S. P. A.*

In considering the general health and welfare of the plantation employees, the importance of good teeth has had but little consideration. We cannot overestimate the value of good teeth. We must consider that prophylaxis is far superior to any curative measures which may be resorted to when decay is shown. Carious teeth have much to do with ill health. "Such conditions as alveolar abscess, enlarged cervical glands which may eventually become tuberculous, inflammatory affections of the throat, eye troubles, pernicious anaemia, arthritic disease, and such conditions as are due to septic absorption, all may be caused by unhealthy teeth. There seems to be no limit to the conditions which may develop to affect the health of the individual who has decaying teeth."*

It is generally understood that bad teeth are the cause of imperfect mastication, which in turn causes indigestion, producing in many cases malnutrition with all its attending consequences, such as anaemia, general feebleness, lack of energy, drowsiness by day and sleeplessness at night, headaches, depression of spirits, and so on. Conditions of this kind do not make for strength on the part of the laborer. On the contrary, his health becomes more and more impaired as a result of them. In some cases the laborer is strong enough and has a reserve of energy which enables him to overcome the bad effects of decaying teeth. To the average laborer, bad teeth mean impaired health and loss of work, or a diminished output.. In carrying on the Industrial Service work we should consider the value of healthy teeth irrespective of age. It is apparent that there are many laborers with teeth in such a condition as to have a disastrous influence on their general health, causing a lessened production of work.

In considering the question of teeth and the plantation worker, it would be well to carry on a test or survey in order to have specific data to show just how

* Extract from Journal of Industrial Hygiene.

badly dentists are needed for plantation work. There is no question but that a great deal of good could be accomplished, and a survey may prove that it would be good business for the plantations to undertake this work.

Many of the larger factories on the mainland employ physicians and dentists who examine all persons who apply for work. If an applicant is accepted but has bad teeth he or she has immediate attention, and the teeth are put in such a condition as not to interfere with general health or production. Should the worker desire any bridge, crown, or gold work, it is at his or her expense. Once each month the teeth of all employees are examined and such dental work done as is necessary.

A system similar to this would no doubt operate well on the plantations, and a survey will no doubt prove that a dentist would be able to serve more than one plantation.

The amount of money to be expended by the plantations for the general welfare of the workers is necessarily limited. Therefore, it is well to consider that which will do the most good. It appears from the data at hand, without the benefit of a local survey, that a great deal of good could be accomplished by employing dentists for plantation work, and that the increase in the production of the workers who are improved in health and morale through dental treatment would prove it to be a good business proposition for the plantations.

With Reference to the Changing of Old Lap-Seam Boilers to a Butt-Seam Construction.*

Not long after the steam boiler came into general use in America, considerable discussion was aroused with respect to the question of limiting the life of a boiler. Numerous instances of serious accident, which it seemed impossible to account for, had impressed many with the idea that a boiler, like any other piece of apparatus, was subject to deterioration from constant use and that therefore it would be best to take a boiler out of service after a certain period. In fact, a number of concerns followed this practice. The majority of boiler users and engineers, however, felt then as they do now that rigid inspection would safeguard their boiler plants and would furthermore be of greater service in the interest of economy, for it was admitted that many boilers had served for twice the life that, by some, had been allowed for safety.

The plan of relying on inspection for a forewarning was adopted and served well, but there were a number of unaccountable explosions in boilers of relatively short life. At the time, the majority of boilers in use were constructed with a longitudinal lap joint. A series of investigations was conducted to study the stress conditions in this type of joint, and it was found that the construction, both from its fundamental shape and the conditions of manufacture, presented a most dangerous condition.

In The Locomotive for April, 1905, there appeared an account of the disastrous boiler explosion at Brockton, Mass., on March 20, 1905, and also an article

* The Locomotive, January, 1921, pp. 141-146.

on the "Lap-joint Crack" to which type of defect the explosion was said to be due. For the sake of clearness we shall present here some of the more important points which were brought out in the last-named article.

When a boiler plate is rolled to a cylindrical form, the edges of the plate, in passing through the rolls, are not gripped as effectively as is the middle of the plate, so that the ends are left somewhat flat. The condition produced is illustrated in Fig. 1. This necessitates the plates being forced together at the edges

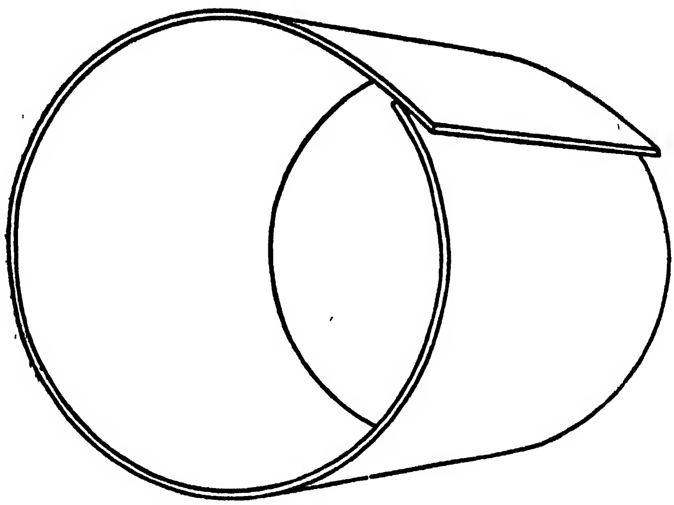


FIG. 1.

and this produces an added stress that persists unless relieved by annealing. In addition to this the plates, if bent after punching, will bend along a line of rivet holes as shown in Fig. 2 in somewhat exaggerated form.

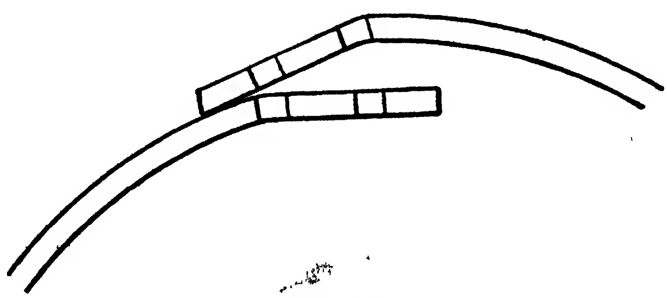


FIG. 2.

The elementary lap joint is illustrated in Fig. 3. If tension is applied as indicated in Fig. 4, the plates, in an attempt to align themselves with the load, will bend along a line running under the outer edge of the rivet heads.

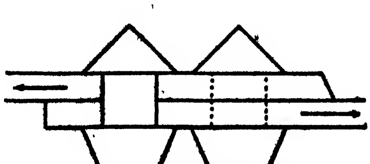


FIG. 3.

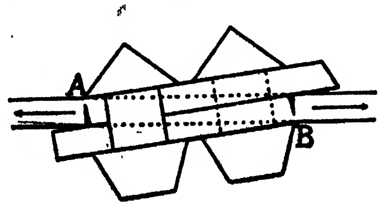


FIG. 4.

The combined effect of all these conditions, together with the constant bending of these joints by changes of pressure when in use, is to impose excessive stresses in the surface of the boiler plate along the line just mentioned. This has produced, in many boilers, a crack which starts always from the inside or covered surface of the inside or the outside plate of the joint as indicated at A and B in Fig. 4. This crack may eventually work its way through the plate until it shows itself by leakage. But in many cases it may develop for some distance along the joint and yet remain absolutely invisible. Eventually the weakness may develop to the point of complete failure and a disastrous explosion.

Inspection is generally accepted as being safe for the determination of the fitness of a boiler for use. The lap-seam crack, however, is invisible to all methods of inspection, except cutting out the rivets and separating the plates or the method described in The Locomotive for October, 1914. Recognizing the insidious danger presented in the lap joint for longitudinal seams in boilers, the Boiler Code Committee of the American Society of Mechanical Engineers formulated the following regulation: (par 380, A.S.M.E. Boiler Code, Edition 1918.)

"The age limit of a horizontal return-tubular boiler having a longitudinal lap joint and carrying over 50 *lbs. pressure shall be* 20 *years, except that no lap-joint boiler shall be discontinued from service solely on account of age until* 5 *years after these rules become effective."*

Some boiler owners may be of the opinion that the longitudinal lap seams of boilers of this type can be changed to butt-strap construction and the boilers kept in service after the time limit. This change of design and construction is not approved, however, by those thoroughly familiar with steam boilers, for, although butt straps and more rivets may be added, the material along the line of the joint, which was abused and tortured by the forming of the lap joint and fatigued by the years of service which subjected it to the expansion and contraction brought about by the many changes of temperature and pressure, would be further abused on the portion of the original construction left after cutting off one side of the lap joint and forcing the edges of the plate into line to form a butt joint.

Assuming that a double-riveted lap joint has been changed to a triple-riveted butt construction, the joint, after placing the butt straps and riveting, would appear as shown in Fig. 5 on page 135 with the rivet holes of the original lap joint at B and the new holes at C. If a defect existed in the plate as shown at A, the joint would be very faulty. Assuming the original joint as having the rivet holes spaced 3¼ inches and the additional holes spaced 6½ inches, if the plate material were defective or contained a lap crack as shown, the failure of the joint would require only the shearing of the rivets in long pitch, or 6½ inches, and the failure of the defective plate.

It might be argued that the exposure of the inside of the lap seam, when the change to a butt seam is made, would reveal the presence of a lap-seam crack. A crack of this nature is, however, often present in a boiler of this construction after years of service although it may not be visible to the naked eye. But, even though no crack exists, it must be remembered that boiler plate, like any other material, becomes fatigued after long years of service, and for this reason, after it has been under stress for many years, it should not be subjected to a change of shape and torture of the material in an endeavor to keep the boiler in service, especially when there is evidence that the altered structure is defective.

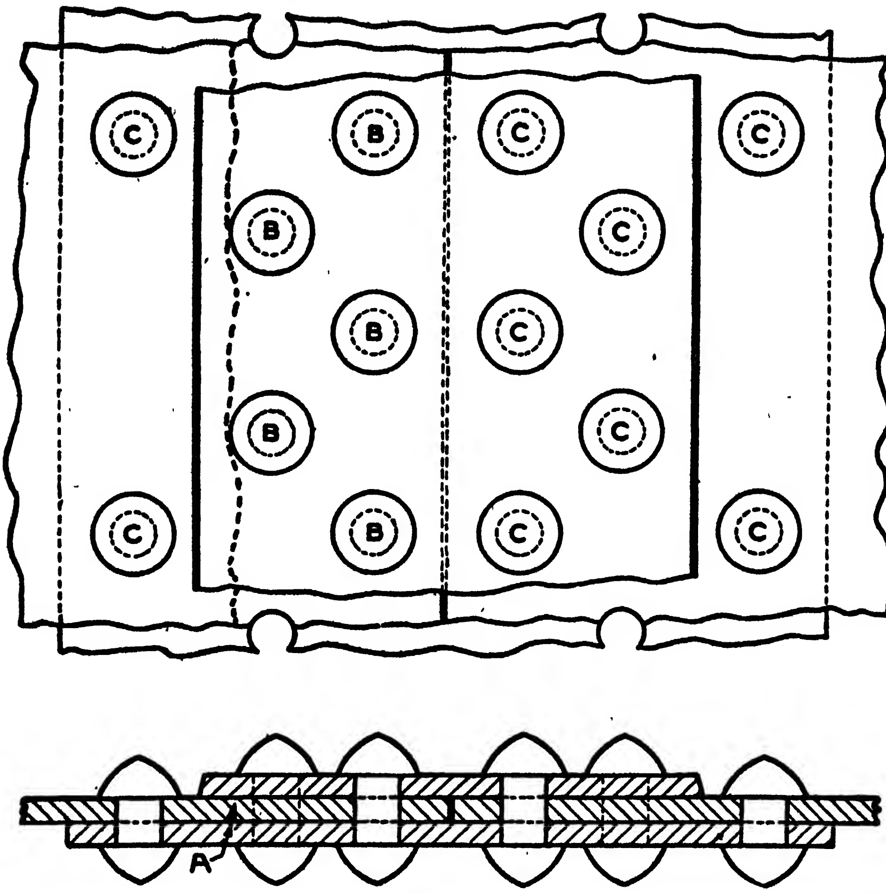


FIG. 5.

The age limit of twenty years is none too exacting, as will be evidenced by an explosion, resulting from a lap-seam crack, of a boiler at the Tallahoma Lumber Co., at Mossville, Miss., on October 21st, 1920. This boiler was less than five years old. The explosion completely wrecked the plant, killed three men and injured four others. There was no negligence on the part of the operators, and there was ample proof that the accident did not result from low water or overheating. On the other hand, the lap-seam cracks could be clearly seen in the boiler plates after the disaster.

Regulations such as we have quoted are not intended to be arbitrary. Railroad companies determine the safe load capacity for each of their freight cars, and if they discover an overloaded car they refuse to transport it. This is done not only to avoid the possibility of straining or breaking the overloaded car, but also to prevent a possible wreck which might result in loss of life, property damage, and delay. In a like manner the Boiler Code Committee requests that steam boilers and pressure vessels be designed and constructd for a safe working pressure and that they be not subjected to overloads. The rule quoted above is sane and economic because it is intended for the protection of life, limb, and property. So also should be regarded the action of the boiler inspector in condemning any construction regarded as unsafe.

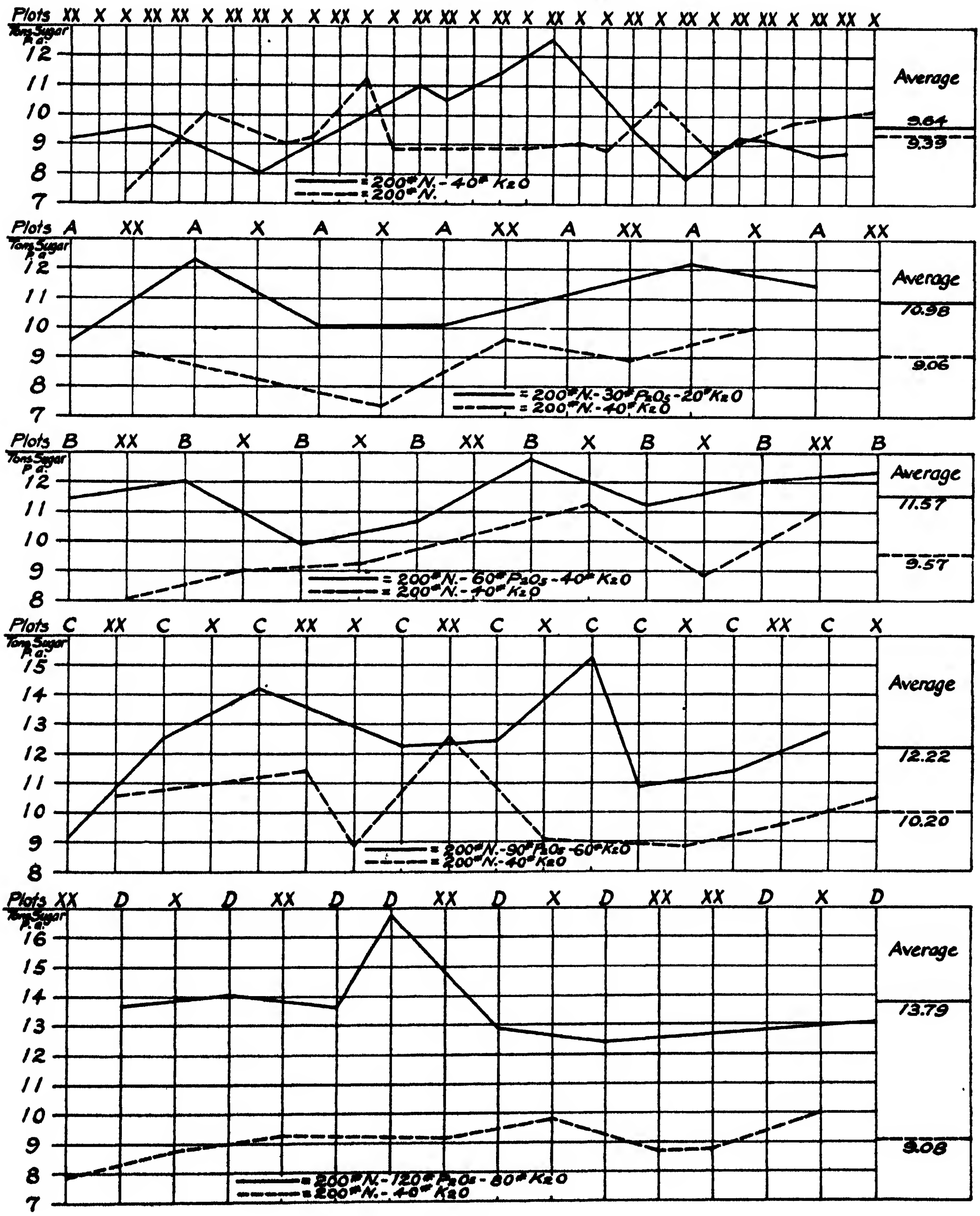
[W. E. S.]

Amount of Fertilizer to Apply.

Oahu Sugar Co., Exp. No. 4, 1920 Crop.

In this experiment a comparison was made between complete fertilizer in varying amounts with nitrogen alone, and with potash.

CURVES SHOWING YIELDS OF INDIVIDUAL PLOTS FOR VARYING AMOUNTS OF PHOSPHORIC ACID & OF POTASH.
D1135 PLOTS ONLY.
OAHU SUGAR CO. EXP. 4, 1920 CROP
FIELD 45 (VIRGIN LAND)



FERTILIZATION—POUNDS PER ACRE.

Plots	No. of Plots	Aug. 30, 1918	Nov. 8, 1918	Feb. 19, 1919	May 27, 1919	Total Pounds		
						Nitrogen	P_2O_5	K_2O
X	15	278 lbs. Nit. Mix.	278 lbs. Nit. Mix.	278 lbs. Nit. Mix.	278 lbs. Nit. Mix.	200	0	0
XX	16	278 lbs. Nit. Mix. 41 lbs. Sul. Pot.	278 lbs. Nit. Mix. 69 lbs. Mol. Ash	278 lbs. Nit. Mix. 0	278 lbs. Nit. Mix. 0	200	0	40
A	7	278 lbs. Nit. Mix. 159 lbs. Acid Phos. 41 lbs. Sul. Pot.	278 lbs. Nit. Mix. 0 0	278 lbs. Nit. Mix. 0 0	278 lbs. Nit. Mix. 0 0	200	30	20
B	8	278 lbs. Nit. Mix. 159 lbs. Acid Phos. 41 lbs. Sul. Pot.	278 lbs. Nit. Mix. 160 lbs. Acid Phos. 69 lbs. Mol. Ash	278 lbs. Nit. Mix. 0 0	278 lbs. Nit. Mix. 0 0	200	60	40
C	9	278 lbs. Nit. Mix. 159 lbs. Acid Phos. 41 lbs. Sul. Pot.	278 lbs. Nit. Mix. 160 lbs. Acid Phos. 69 lbs. Mol. Ash	278 lbs. Nit. Mix. 160 lbs. Acid Phos. 69 lbs. Mol. Ash	278 lbs. Nit. Mix. 0 0	200	90	60
D	8	278 lbs. Nit. Mix. 159 lbs. Acid Phos. 41 lbs. Sul. Pot.	278 lbs. Nit. Mix. 160 lbs. Acid Phos. 69 lbs. Mol. Ash	278 lbs. Nit. Mix. 160 lbs. Acid Phos. 66 lbs. Mol. Ash	278 lbs. Nit. Mix. 160 lbs. Acid Phos. 66 lbs. Mol. Ash	200	120	80

The cane was Lahaina and D 1135, first ratoon, long, and was 28 months old when harvested. The field is at an elevation of approximately 550 feet and is irrigated with mountain water. From January, 1920, to harvest, in November, this field was not irrigated. During this time the rainfall amounted to 23 inches, most of it in January and March.

The schedule of fertilization is shown on page 137.

The results obtained from this crop, as well as those from the plant crop, two years ago, are given in the following tables:

1918 CROP, LAHAINA.

Plots	Fertilizer, Pounds per Acre			Yield per Acre			Gain over adjoining X Plots	
	Nitrogen	P_2O_5	K_2O	Cane	Q. R.	Sugar	Cane	Sugar
A	200	30	20	62.40	7.62	8.19	+ 5.33	+ 0.67
X	200	0	0	57.07	7.59	7.52		
B	200	60	40	66.28	7.71	8.59	+ 10.87	+ 1.33
X	200	0	0	55.41	7.63	7.26		
C	200	90	60	67.44	8.11	8.32	+ 10.80	+ 1.24
X	200	0	0	56.64	8.00	7.08		
D	200	120	80	69.67	8.66	8.04	+ 13.58	+ 1.36
X	200	0	0	55.09	8.75	6.68		

1920 CROP, LAHAINA.

Plots	Treatment	Yield per Acre			Gain Over Adjoining Plots Receiving No Phos. Acid	
		Cane	Q. R.	Sugar	Cane	Sugar
XX	Nitrogen and Potash	45.8	7.29	6.28	+ 1.9	+ 0.47
X	Nitrogen only	43.9	7.56	5.81		
A	N. and K_2O + 30 lbs. P_2O_5	56.3	7.80	7.22	+ 10.3	+ 1.01
X and XX	N. and K_2O + No P_2O_5	46.0	7.41	6.21		
B	N. and K_2O + 60 lbs. P_2O_5	66.6	8.25	8.07	+ 24.1	+ 2.35
X and XX	N. and K_2O + No P_2O_5	42.5	7.41	5.72		
C	N. and K_2O + 90 lbs. P_2O_5	70.2	8.03	8.75	+ 23.1	+ 2.41
X and XX	N. and K_2O + No P_2O_5	47.1	7.41	6.34		
D	N. and K_2O + 120 lbs. P_2O_5	66.7	7.43	8.98	+ 23.0	+ 3.06
X and XX	N. and K_2O + No P_2O_5	43.7	7.41	5.92		

1918 CROP, D 1135.

Plots	Fertilizer—Pounds per Acre			Yield per Acre			Gain Over Adjoining X Plots	
	Nitrogen	P_2O_5	K_2O	Cane	Q. R.	Sugar	Cane	Sugar
A	200	30	20	59.42	9.68	6.14	+ 7.67	+ 0.68
X	200	0	0	51.75	9.47	5.46		
B	200	60	40	60.52	9.71	6.23	+ 10.09	+ 0.78
X	200	0	0	50.43	9.26	5.45		
C	200	90	60	64.83	10.51	6.17	+ 15.75	+ 1.40
X	200	0	0	49.08	10.28	4.77		
D	200	120	80	65.54	11.02	5.95	+ 17.85	+ 1.37
X	200	0	0	47.69	10.19	4.68		

1920 CROP, D 1135.

Plots	Treatment	Yield per Acre			Gain Over Adjoining Plots Receiving No Phos. Acid	
		Cane	Q. R.	Sugar	Cane	Sugar
X	Nitrogen and Potash	72.6	7.53	9.64	+ 3.5	+ 0.25
XX	Nitrogen only	69.1	7.36	9.39		
A	N. and K_2O + 30 lbs. P_2O_5	78.7	7.17	10.98	+ 11.1	+ 1.92
X and XX	N. and K_2O + No P_2O_5	67.6	7.46	9.06		
B	N. and K_2O + 60 lbs. P_2O_5	89.5	7.73	11.57	+ 18.5	+ 2.00
X and XX	N. and K_2O + No P_2O_5	71.0	7.46	9.57		
C	N. and K_2O + 90 lbs. P_2O_5	91.0	7.59	12.22	+ 15.0	+ 2.02
X and XX	N. and K_2O + No P_2O_5	76.0	7.46	10.20		
D	N. and K_2O + 120 lbs. P_2O_5	99.5	7.21	13.79	+ 31.7	+ 4.71
X and XX	N. and K_2O + No P_2O_5	67.8	7.46	9.08		

The addition of potash made very little difference in the yields, as shown by comparing the yields of the X and XX plots. This was to have been expected, as these soils are high in potash, containing about 0.8% of total acid soluble K_2O.

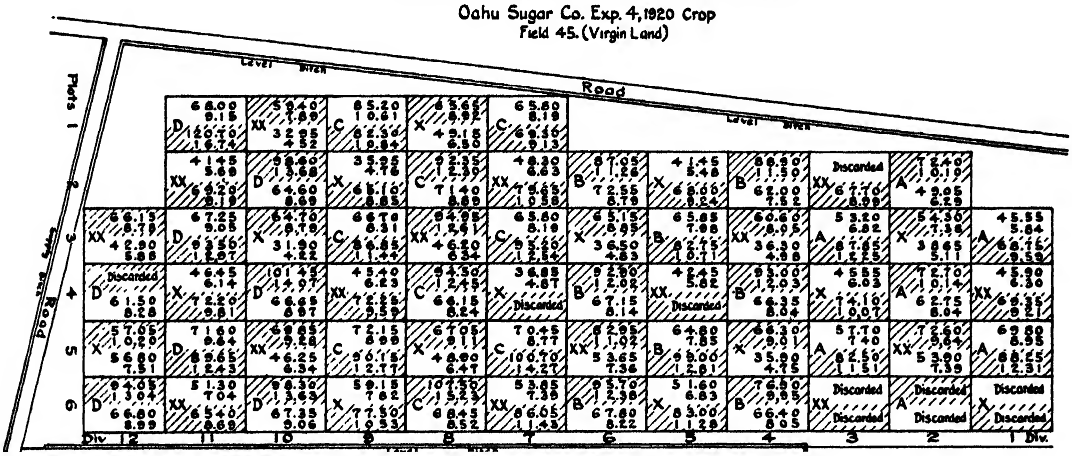
As all the plots received equal amounts of nitrogen, 200 pounds per acre, the rather large gains in cane and sugar for the different treatments are due almost entirely to the addition of phosphoric acid. Each increase in the amount of phosphoric acid applied produced a further gain in sugar up to the limit of phosphoric acid application, which was 120 pounds per acre of P_2O_5.

We plan to add larger amounts of phosphoric acid to the next crop to determine what the profitable limit is on these lands.

The general plantation practice on these fields has been to put on about eight hundred pounds of so-called "high-grade" fertilizer per acre.

This fertilizer contains about 8% P_2O_5. This gives 64 pounds of P_2O_5 per acre. Assuming similar conditions as those of the experiment (chemical analyses indicate that practically all the upper red soils of that district are of that nature), the addition of 60 pounds more per acre of P_2O_5 should increase the yield of, say, H 109, D 1135, or H 456 by one or two tons of sugar when all other conditions are favorable. Sixty pounds of P_2O_5 would be supplied by 320 pounds of acid phosphate, and would not cost more than five or six dollars per acre.

AMOUNT OF COMPLETE FERTILIZER TO APPLY.
Oahu Sugar Co. Exp. 4, 1920 Crop
Field 45. (Virgin Land)



Summary Yields For Each Treatment.

Plots	Fertilizer Elements Applied Lbs P A			Yields Of Sugar Tons Per Acre			
	Nitrogen	P_2O_5	K_2O	Lahaina	Gain Over No Phos. Acid	D1135	Gain Over No Phos. Acid
XX	200	-	40	628	+ 047	964	+ 025
X	200	-	-	581	-	939	-
A	200	30	20	722	+ 101	1098	+ 192
X, XX	200	-	40	621	-	906	-
B	200	60	40	807	+ 235	1157	+ 200
X, XX	200	-	40	572	-	957	-
C	200	90	60	857	+ 223	1222	+ 202
X, XX	200	-	40	6.34	-	10.20	-
D	200	120	80	898	+ 306	1379	+ 471
X XX	200	-	40	592	-	908	-

Key:-
Ruled Area = D1135
Clear Area = Lahaina

In the experiment discussed above, dealing with both D 1135 and Lahaina cane, the yields of the D 1135 exceeded those of the Lahaina by 50%. The average yields of all plots were as follows:

Variety	Tons per Acre		
	Cane	Q. R.	Sugar
Lahaina	52.88	7.63	6.93
D 1135........	78.28	7.42	10.55

It is also interesting to notice that, not only were the yields of the D 1135 50% better than those of the Lahaina, but that the juices of the D 1135 were better than those of the Lahaina. This cane, as previously mentioned, was harvested very late and was very dry when harvested. Two years ago, this same field was harvested in March, after a very wet winter. The quality ratio of the D 1135 was then very nearly ten. This would seem to indicate that the quality of D 1135 juices can be very materially improved by properly drying the fields before harvesting.

J. A. V.

A Natural Enemy of Mosquito Larvae.

Very few invertebrate enemies of mosquito larvae have been recorded, and it is therefore of interest to know that in Buenos Aires there is a planarian worm that attacks them. The following summary of the original paper by A. B. Lischetti appears in the October number of "The Review of Applied Entomology":

"The fact that 30 larvae of *Stegomyia fasciata* (*Aedes calopus*), placed in a glass tank of water for breeding purposes, disappeared within two days led to investigations to determine the reason. Thirty larvae of *Culex* sp. introduced into the tank suffered the same fate, only a few fragments being left. An examination of the flora and fauna of the water was then made, and revealed among other things a number of worms of the genus *Planaria*. The fact that young mosquito larvae disappeared completely and that only the harder portions of older ones were left, indicated that they were devoured by the *Planaria*, which was the only living organism in the water capable of such action. Experiments were then made with 100 cc. drinking water into which were placed six *Planaria* worms, and in successive batches of about 10 to 20, 108 larvae of *Culex* sp. from 3 to 4 mm. long. A table shows the length of time taken to dispose of the various batches of larvae; within four hours the six *Planaria* had devoured a total of 106 larvae, only two particularly large individuals escaping the general fate. The same six *Planaria* were immediately transferred to another vessel containing 200 *Culex* larvae of 4 to 5 mm. length, which they immediately attacked and continued devouring with short intervals of rest. By midnight many larvae were dead or dying, and by 8 a. m. next day all had either disappeared or were clinging to the bottom or sides of the receptacle.

"The habits of these worms have been studied, and are described. The presence of mosquito larvae in the vicinity causes some excitement among them, and the larvae are attacked when their siphons are brought to the surface for a few seconds. The worm applies one of the lateral lobes of its head to the siphon of the larva, to which it adheres by means of the viscous substance with which it is covered. If the larva tries by means of its mouth-parts to rid itself of its enemy, as is frequently the case, both mouth-parts and siphon adhere to the worm, which, as soon as it has secured its prey, drops with it to the bottom of the receptacle. It then punctures one of the larval segments and drags out the whole body content of the larva, leaving only the head and skin. Adult larvae, on account of their strength, and pupae on account of their activity, can almost always escape the attacks of *Planaria*.

"The experiments described indicate that this natural enemy might be used artificially for the destruction of mosquito larvae, but further information must be obtained regarding the distribution and habits of the worm, its resistance to meteorological conditions, etc., before its value in this connection can be determined. The present notes are given with the object of interesting students in the question and suggesting a field of investigation to them."

F. M.

Effect of Salt on Cane.

Oahu Sugar Company Experiment No. 20 (1920 Crop).*

SUMMARY.

This experiment was planned to determine the effect of common salt (NaCl) on the growth of cane and on the quality of the juices. As originally laid out, this experiment involved Lahaina and H 109 for the crop of 1918, but the combined effect of Lahaina disease and eye-spot was so serious that no results were obtainable.

After harvesting the 1918 crop, the H 109 area was replanted with D 1135 and the same experiment continued for 1920 crop on Lahaina and D 1135. Again Lahaina disease so damaged the Lahaina area that only the D 1135 was avilable from which to secure data.

The treatment for both crops consisted of applying salt at the rate of 0, 2000, and 20,000 pounds per acre to each crop in 20 equal applications at two-week intervals. All plots received uniform fertilization, for the 1918 crop consisting of 750 pounds complete fertilizer and 484 pounds of nitrogenous mixture, and for the 1920 crop, consisting of 800 pounds complete fertilizer and 525 pounds nitrogenous mixture.

The addition of 2000 pounds of salt per crop seemed to have had little or no ill effect on the yield, but the addition of 20,000 pounds has caused a loss of 7.95 tons cane or 1.38 tons sugar. The following tabulation shows the yields for the different treatments and also the gain or loss when compared with the adjoining X plots:

Plot	Treatment	Yield—Tons per Acre		Gain or Loss in Tons Over Adjoining X Plots	
		Cane	Sugar	Cane	Sugar
AA	1 ton salt per acre per crop..	92.9	13.99	+ 1.39	+ 0.53
AX	No salt	91.5	13.46		
BB	10 tons salt per acre per crop	90.2	13.05	— 7.95	— 1.38
BX	No salt	98.15	14.43		

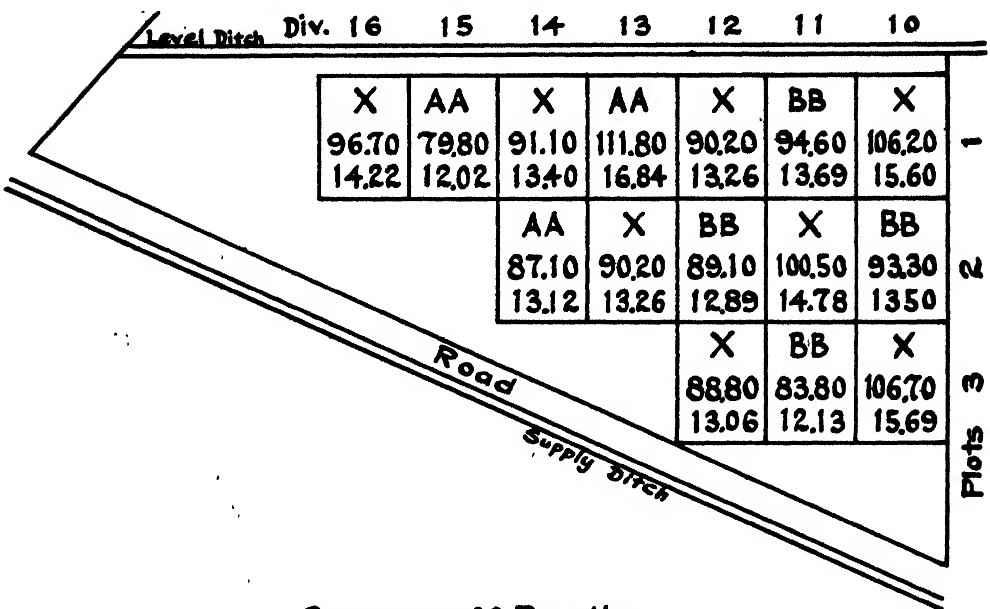
From this tabulation one might be led to believe that a small amount of salt had a stimulating effect on the cane. However, a detailed study of the plot yields shows that this apparent greater yield is caused by one plot. Upon discarding this exceptionally high-yielding AA plot, a slight loss in both cane and sugar is shown.

Salt seems to have had no effect on the juices. While there are slight

* Experiment planned by L. D. Larsen and harvested by Y. Kutsunai.

Effect Of Salt On Cane Growth

Oahu Sugar Co. Exp. 20, 1920 Crop
Field 49 (New Land)



Summary Of Results

Treatment	Yields Per Acre			Gain or Loss Over No Salt Plots	
	Cane	Q.R.	Sugar	Cane	Sugar
No Salt	91.51	6.80	13.46		
1 Ton Salt	92.90	6.64	13.99	+1.39	+0.53
No Salt	98.15	6.80	14.43		
10 Tons Salt	90.20	6.91	13.05	-7.95	-1.38

variations, they are so small as to be within the limits of experimental error. The following shows the juices obtained:

Treatment	Brix	Pol.	Pur.	Q. R.
No salt	22.56	19.59	86.84	6.80
1 ton salt.......	23.09	20.03	86.75	6.64
10 tons salt.....	22.78	19.45	85.38	6.91

DETAILS OF EXPERIMENT.

Object: To determine the effect of common salt (NaCl) on the growth of cane and the quality of the juices.

Location: Field 49, Section 11, Divisions 10 to 16 inclusive.

Crop: Lahaina and D 1135, first ratoons, long; plant crop was on virgin land.

Layout: No. of plots, 15. Size of plots, 1/20 acre each (39.5′x 55′), consisting of 10 single rows. Each plot is one watercourse wide.

Plan:

X plots, 0.

AA plots, 2000 pounds NaCl per acre.

BB plots, 20,000 pounds NaCl per acre.

This salt to be applied in 20 doses at intervals of about two weeks.

Fertilization: Uniform to all plots, as follows:

August, 1918, 400 pounds C.F.; October-November, 1918, 262.5 pounds N.M.; February-March, 1919, 400 pounds C.F.; May-June, 1919, 262.5 pounds N.M.

C.F. = 10% N. (7% sulfate, 3% nitrate), 8% P_2O_5, 1% K_2O.

N.M. = 18% N. (½ nitrate, ½ sulfate).

PROGRESS OF WORK.

July 7, 1918—Cut back.
August 28, 1918—First fertilization and first application of salt.
November 6, 1918—Second fertilization and sixth application of salt.
February 24, 1919—Third fertilization.
February 28, 1919—Fourteenth application of salt.
May 22, 1919—Twentieth application of salt.
June 5, 1919—Fourth fertilization.
August 5-7, 1920—Experiment harvested by Y. Kutsunai.

R. S. T.

Japanese Canes. *

By D. W. May.

We have at the station (Mayaguez, Porto Rico) two varieties of cane that came out of India, but generally known as Japanese canes. They are very nearly alike, having peculiar characteristics quite different from other canes commonly grown on the island. They are very slender, but stool heavily, and soon cover the ground. They have been grown to some extent in the Southern States as forage principally. Their outstanding feature with us, however, is that they are free from the matizado or yellow stripe disease, which is causing us concern at this time. When the matizado first began to appear extensively in Porto Rico, the station brought from St. Croix several tons of the variety known as Kavangire, while it already had some of the variety known as Zwinga, which we were growing for forage for our cattle. Since a great deal of these canes have been planted, especially on the western end of the island, where the matizado has given us the most trouble, it is well to look into their value from a sugar-making standpoint to determine whether we shall extend the plantings or gradually eliminate them.

It cannot be said that these are first-class milling canes. From the standpoint of plant improvement they may be said to be wild canes. This is indicated by the smallness of the stem and the amount of trash. In the West Indies we are prone to look upon a cane with a small stem as undesirable, and in all our cane-breeding work we have sought large canes. In the East Indies, where labor is cheaper than with us, and where a great many women and children are employed in the cane fields, they pay more attention to canes that stool well; that is, that give a great many stalks in the hill. It is this that we consider the greatest defect of the so-called Japanese canes. On the other hand, we find that these

* From Agr. Ext. Notes, Porto Rico Agr. Exp. Sta., No. 31, Jan., 1921.

canes give a large tonnage and have a further advantage of tillering and growing so rapidly as to quickly cover the ground, shading it so that weeds and grasses cannot grow and less cultivation is therefore required. On the other hand, the variety Kavangire takes longer to mature than the canes usually grown in Porto Rico. Under twelve months this cane tested from 9 to 13 per cent sucrose and from 60 to 80 per cent purity. At fifteen months it averaged 14 per cent sucrose and 86 per cent purity. At eighteen months, or *gran cultura,* it ran up to 15.9 per cent sucrose. In this connection it is advisable, where possible, to follow the growth of the cane with chemical control. In Java in many instances they test their canes for ripeness by drawing stalks and making polariscope tests from time to time to determine when it is at the best stage for harvesting. It might be advisable for us to follow the same practice. It is especially valuable with the Kavangire cane and also with the Rose Bamboo and Yellow Caledonia. These canes are long in maturing, and with the Bamboo cane especially, as it does not arrow, it is difficult to determine by appearance when it is at the best for cutting. If cut too soon or too late the glucose ratio is very high.

A mill test was made at Guanica of 2.23 acres of the Kavangire cane harvested about three months before it was planned to cut the same, due to its having been burned. It was 14 months old when cut. The yield was 44.75 tons per acre. The normal juice ran 13.70 Brix, 10.59 sucrose, 77.31 purity, and 1.76 glucose. The total sugar recovered per acre was 3.53 tons.

At the same time the Kavangire cane was cut, there was harvested, from the same tablón at Santa Rita and alongside, seedling cane D 117. The yield was 49.7 tons per acre. The analysis, Brix 15.72, sucrose 13.24, purity 84.22. Yield of sugar 96° was 5.25 tons per acre.

In our first planting of the Kavangire cane at the station September, 1917, harvested January, 1919, the yield was in holes five feet apart, 95.9 pounds per hole. This calculated at the acre rate would amount to 83.56 tons. Several tests were made, grinding the cane in a small hand mill. The average sucrose was 12.2 per cent, purity 81.23 per cent.

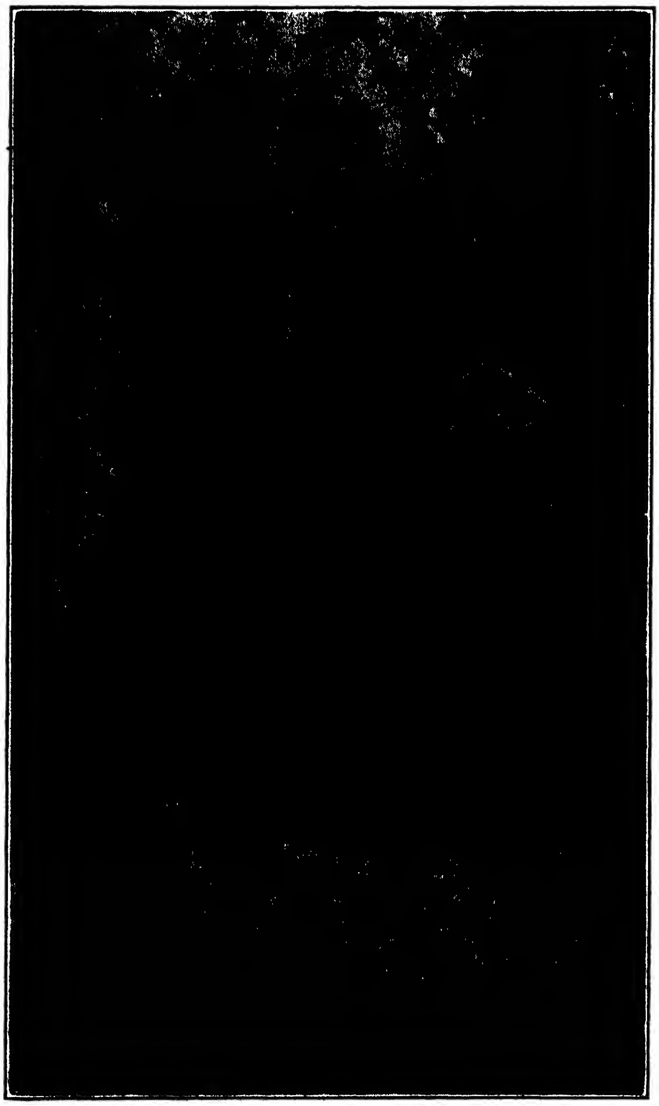
In a field of the other variety of so-called Japanese cane known as Zwinga, planted on high land for forage, the yield in 7 months 10 days was 33⅓ tons per acre cut for cattle. This cane would have grown much larger if it had been allowed to mature. The results are given here to show that these canes are of value as forage and may be utilized profitably for that, should the price of sugar drop to a point where it would not pay to harvest them.

Therefore, in summing up the matter, we would advise our cane growers to give these Japanese canes, known as Kavangire or Yuba and Zwinga, a further trial, especially as the matizado disease is giving us some trouble, although the conditions are improving. We should bear in mind the fact, however, that we should continually seek for better canes than we are now growing. With the hundreds that are coming out every year propagated by plant breeders in various tropical countries, we should continually seek those that will give us the greatest amount of sugar with the minimum amount of labor. In doing this we should not take the results in any one country or any one locality, because some varieties of canes will do best in certain situations or on a given type of land, while an entirely different one will give best results under other climatic conditions or even on a different soil on the same estate.

[H. P. A.]

An Ilongot Cane Press.

The illustration shows a primitive device for extracting juice from cane. The photograph is furnished us by Mr. C. E. Hoye, associated with the public school system of the Philippines, who says that the cane press is "in use among the Ilongots of north Luzon—perhaps our wildest Malay tribe—where I was stationed two years ago. It is worked by foot pressure on the string, which sets



the pole swinging up and down, when the cane stalks are pushed between the pole and the block of wood. So far as I know the juice is only used as a fermented drink. The cane grown there is the largest in the Philippines, I believe; the people tie the stalks to the trees to keep them standing upright; the land in this section is entirely public land, and the valleys are extremely fertile. A meter wide trail is now being built across this country, the first attempt to open it up."

H. P. A.

Ultraviolet Rays and the Sugar Cane, Pineapple, and Banana Industries.*

By T. Tsuji.

The author, studying the action of the ultraviolet rays on chlorophyll in sugar cane, found that germinated and intact canes cultivated in moist soil with exclusion of light at 22° C. (71.6° F.) grew but remained etiolated for 30 days. After this period, one-half of these plants were exposed to direct sunlight, the other half to the ultraviolet rays of a quartz mercury vapor lamp of 110 volts and 4 amperes for 2.5 hours. The former plants remained yellow, while the latter assumed a deep green coloration.

Of three rows of sugar cane, one was so shaded with colored glass as to decrease by 50 per cent the ultraviolet rays of the sun; the plants of the second were exposed to open sunlight; those of the third were exposed to the ultraviolet rays of the sun and of a weak mercury lamp. Fertilization was the same in each case. After some months of growth, the plants of the first row had gained 1.25 pounds; those of the second, 2.8 pounds, and those of the third, 3.33 pounds. These results, and the fact that the period of growth to maturity was reduced from 20 to 11 months, suggest the practicability of using ultraviolet rays for increasing cane crop yields and decreasing the time required per crop in Hawaii.

It is claimed that the action of ultraviolet rays on carbon dioxide and hydrogen in the nascent state in the presence of potassium hydroxid determines a photosynthesis. The formaldehyde thus produced is condensed to sugar under the influence of the rays, and carbon dioxide and water vapor are also combined to form sugar and other carbohydrates. The canes in the second row above mentioned had 30 per cent and those in the third row 38 per cent more sugar than those in the first row.

The influence of ultraviolet rays in producing sulfuric acid from sulfur dioxid, oxygen, and water is mentioned in connection with suggested possibilities.

Ultraviolet rays with carefully-controlled daily exposure lasting for 40 minutes were found to ripen pineapples more completely and satisfactorily than was usual for these fruits.

Etiolated banana leaves developed in five hours a deep green color. Banana leaves and stalks exposed to ultraviolet rays after being cut and kept in water remained perfectly fresh for two weeks, at least twice as long as those kept in diffused daylight. This is thought to indicate a means of preserving and ripening with improvement bananas for shipment to distant points.

The problem is how to produce and employ practicable apparatus for the application of the shorter ultraviolet rays to sugar cane, pineapple, and banana culture.

[H. P. A.]

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* From Exp. Sta. Recd., Vol. 43, No. 8, p. 730. Original appeared in La. Planter, 60 (1918), No. 26, pp. 413, 414; also in Gard. Chron., 3, ser., 66 (1919), No. 1719, p. 283.

The Sugar Cane (Arundo Saccharifera). Tubu.*

In passing, I must give an account of sugar cane also, for there are various plants in this collection which are compared with it. I have, too, certain additions to make which are not found in the books of Europeans, and I shall explain certain questions and difficulties which arise in connection with this reed.

The sugar-cane plant, as it is cultivated in India today, is a stalk of equal thickness, curving a little at the bottom, and growing, with no lateral branches, to a height of eight, ten, and twelve feet, though I have seen some stalks as long as seventeen feet. Generally it is as thick as two fingers, sometimes as thick as two thumbs. It is divided into many short sections, three, four, and five horizontal fingers long, and bulging a little in the middle. The lower part is bare, while the upper part bears at each node a large leaf. This leaf is much larger than in all other kinds of reeds, being four feet long, three fingers wide, running to a sharp point at the end, striated lengthwise, with a flat white vein in the center, wrinkled to the touch and sharp enough to cut along the edges, of a pale gray-green color.

It never produces flowers and seed unless it has stood for several years in a stony place. Then a large reed-like panicle grows out at the top, as in Sorghum, but much lighter, composed usually of soft white down in which lies hidden the chaff-like seed.

In these Oriental countries I have seen three species of sugar cane, differing in no way except in the color of the stalk.

The first and most common species is the white with very long joints, more than five horizontal fingers long, usually light yellow or white on the outside. This species has a very thin rind, yields a very large amount of juice, and supplies the most sugar.

The second is the brown or red species. It has very short joints, a rather hard rind and pith, and on the outside is brown or striped with brown and white, but always in such a way that the predominating color is brown. This kind gives less juice, but is sweeter than the preceding. Some wish to make another species of that cane which has a rather thin stalk, striped on the outside with brown and black. From this they call it the black cane. Its leaves have a brown midrib.

The third species has a very thin stalk and rind, is not more than a thumb thick, and has green stripes and long joints. It has very sweet sap and yields a very large amount of sugar. It is therefore extensively cultivated by the people of Java, around Zuroebaja, for its sugar.

All three of these species are filled with a sweet, watery, spongy pith which is made up of long fibers in such a way that its sweet juice can be easily sucked out if the hard rind is first removed. In all other particulars, the form of this (reed) is sufficiently well known.

There are two methods of cultivating sugar cane. The first is that of the Javanese. They take a large level tract, well exposed to the sun, damp and warm, where the soil is soft, brown and rich, and turn it up with a plow. They mark

Rumphius, Herbarium Amboinense, Book VIII, Chapter XXVI. (Published in 1750.) Translated from the original Latin by Miss Susan G. Clark.

these fields off in furrows, just as we do those in which cabbage is planted. In the raised ridges, on both sides, are stuck ends cut from the old stalks of sugar cane, or the shoots which grow here and there from its nodes. A little of each joint is left, but the leaves are cut off all around.

These ends, placed in the ground four, five or six together, obliquely or in circles, send out roots and produce new stalks which mature in the ninth or tenth month. They do not wait for the flowers to come out, however, for by that time the cane has lost its best juice.

The second method is best suited to regions where they do not wish to secure a large amount of sugar, but to use the cane for food. It is done by placing old stalks in the ground, just as with the grape-vine. Two furrows are made, or parallel ridges. In each an old stalk is placed and covered with a little earth. Then, from almost every node a new plant starts which grows into a new stalk. If these are too close together, here and there one or two are cut off. When these stalks come up the ground must be carefully freed from all other growing vegetation, in order that the cane may be thriftier.

The people of Amboina do not spend much labor on planting this reed. They just dig holes about half a foot deep here and there, after they have first gone over the ground and burned all standing vegetation. In these holes they place these ends or shoots, four or six in a circle. When these grow out they again weed the ground. They cultivate this cane in the way just mentioned.

I have learned that in western India, by setting out stalks, sugar cane can be grown in one and the same field for five years before new land is required.

In these islands this cane does not last for more than three years. Then it dies. Also, the same land cannot be used for more than three consecutive years. The Javanese cut off the ripe stalks in such a way that three or four nodes are left above the ground. From these, new stalks again grow out, and so they can gather this cane twice or three times from one field before this (the field) is changed, but the last crop is in no way as rich as the first.

The stalks which have been cut and stripped of leaves are crushed between two rollers made of hard Cussambi wood, one of which is turned by caribao. Then the juice which has been pressed out is carried by a flume made of caribao hide to large vats. From these it is carried to others to be cooked. These vats have on the lower side an iron kettle which rests on an oven. The sides of this kettle are supported by bricks built up high and obliquely, and so plastered over with lime that the whole thing looks like a huge kettle.

Into this kettle the juice is poured and under it a hot fire is built. As it boils down they add new juice, letting the fire die down gradually, until the juice is brown and viscid. Then they pour it into deep earthen pans or large earthen jars, which are placed in a large smoke-room, where it is dried into sugar. The upper part is white and lumpy. From this it is called cake-sugar. The lower part is yellowish-brown and is called muscovado sugar.

From the white sugar the Chinese make sugar-candy. They melt the sugar again in a large kettle, mix with it the whites of eggs, carefully stir it, and finally add a little chicken fat, saying that this is required to make the sugar clear.

The Chinese in their own country, or living in places where there are no Moors (meaning Brahmins?), take melted lard instead of chicken fat. But they hide this (practice) from that nation, that they may not lose their trade, for the

reason that the Moors generally refuse to eat this sugar unless they are convinced that it has been made and prepared by their own people.

Furthermore, let everyone who buys any sugar in Java, packed in baskets, be warned to examine these first with due care, for the deceitful nation of the Chinese is wont to place good sugar on top, but dirt, ashes or dried leaves below. Sometimes, too, they mix muscovado sugar with the black palm-tree sugar, made from the Saguer palm, or they boil these two juices together, a fact that is discovered when it becomes moist and slimy.

After the sugar-candy is boiled it is poured into pans or jars in which a wicker (screen) made of split cane or bamboo has been placed. To this the sugar adheres and hardens, and as a result it sometimes happens that small bits of cane fiber are found. These are not the bristles of pigs, as some falsely believe.

From the whitest and best sugar there is made a very fine hard sugar-candy, like crystal, which is called masculine sugar. From the cheaper dark sugar a yellow sugar-candy is made which is much more brittle and less choice, but which, at the same time, is richer and sweeter than the former. This is called feminine sugar.

In China the third species of cane is most common. It has a very thin stalk and rind, you remember. The Chinese call this *Tecsia,* from the word *Tec*; that is, *Bamboo.* They use it solely for obtaining sugar. All other coarser, larger sugar canes they call *Camsia,* or, by a better pronunciation, *Gamsia.*

Tecsia is scarcely a thumb thick, generally yellowish like the *Boeloe Swangi,* and so soft and tender that its rind can easily be bitten into and split lengthwise. Its species is *Toeboe Marasoli,* brought from Boeroe to Amboina. This cane, too, is yellowish, marked with a few green stripes. It is said to have been brought to these islands from Ternata by one Huccum Marasoli. Very often this cane deteriorates and becomes short-jointed, with a hard rind like the common white sugar cane. In my opinion they are merely two varieties of the abovementioned third species.

Names: Latin, *Arundo Saccharifera.* Malay, Javanese and Baleya, *Tabu* and *Tebu,* from its many nodes. In Amboina and Bandas, *Tewa.* In Ternata, *Uga.* Chinese, *Camsia.* The condensed juice is called in Latin *Saccharum* and *Zuccharum.* Malay, *Gula,* or more properly *Sacchari,* and the sugar-candy *Saccar,* or *Gula Batu,* meaning rock-sugar. In Chinese, *Tung,* and the sugar-candy *Tungsung.*

The word *Gula,* if not of Persian origin, may be derived from the Arabian *Cohl,* meaning thickened juice.

The word *Jagara* or *Jagare* is very similar to the word *Saccharum.* By it the people of Hindustan mean any sugar which is made from the sap of trees, especially of the Lontar tree, and it is uncertain which is the older word among the Indians, *Saccharum* or *Jagare.* Above, in Book I, Chapter 8, we say that in our opinion *Jagare* is the oldest, because, without doubt, the practice of boiling sugar from the sap of the Lontar and Calappus trees was the oldest, making *Jagare* the earliest word. But now that we think of it again, the word *Saccharum* was known to Pliny and Dioscorides, and from their descriptions it may be decided that their *Saccharum* had nothing in common with the poor quality *Jagare* generally called by us black sugar. Now, from this I should conclude that

Saccar is the oldest and first Indian work, and that *Jagare* was either derived from it because of the similarity of sound, or is a distinct word, quite apart from it. The art of making sugar from the sap of trees is not so old among the Indians.

Concerning the place and use of sugar cane we shall not say much here, merely mentioning that this cane is extensively cultivated in Bengal, Siam and Java for making sugar. In Bali, Celebes and the Moluccas, syrup is made from it. This is properly called *Gula,* and is used in foods, but it serves our people as beer. In Amboina and other islands of the east where the sea air is rather cool and the soil poor, the cane is correspondingly thinner and poorer. It is not cultivated much, and is generally eaten in its raw state.

Goela, or the syrup made from sugar cane, is called in Ternata *Manis,* and is chiefly used for making the drink *Kilang*. The thin syrup is poured into jars and a small dish of mash of beer or of some other drink is added to it. In this way it is allowed to ferment for several days. After this three or four crushed roots of Lanqua are put in, and again it is fermented. Finally a little bundle of Cumin and Cinnamon is added, and then for a month it is left to itself, half buried in the ground. The jar must not be sealed, lest it burst. This drink readily intoxicates, but causes no headaches. Men grow fat on it, and the men of Timor and Rotte make this their boast for their *Goela,* which they make from the Lontar and call *Coli.*

Muscovado sugar and sometimes even the rind of the cane itself are mixed with *Doepa* and *Astangi,* and give forth a sweet fragrance when placed on live coals.

For the rest, we shall set forth in passing some curious questions and explain them according to our best judgment. First, was our sugar known to men of antiquity; second, what is the difference between our sugar and theirs; and third, when did our sugar come to the knowledge and use of the western world.

As to the first, we thoroughly agree with Matthiolus in his Commentaries on Dioscorides, Book 2, Chapter 75, on honey, and we say with him that the sugar mentioned in this chapter of Dioscorides, and which was barely known to the men of antiquity, was condensed juice or *Gummi,* taken from this same cane from which we today secure and prepare sugar, as Dioscorides' words in the passage cited clearly show, that is, was secured from cane.

In answer to the second question, we say that, although the sugar of the ancients was secured from this same cane, there is nevertheless this difference between theirs and ours. Theirs was condensed juice, like drops of gum, white, brittle, easily crumbled in the mouth, and having the form of fine salt. For this reason it was called by them Indian salt. It had to exude of its own accord, under the heat of the sun, from the old stalks of cane, and harden around the nodes. The tear-like drops were never larger than a filbert, and so in the days of Pliny sugar was very expensive. Without doubt, at that time the process of making sugar was not yet known to the natives, who were satisfied with that which nature produced from this plant and gave them of her own accord, until they learned the process mentioned either for ~~the sake~~ of profit or from the Chinese. At any rate, even to this day sugar is prepared in Java by the Chinese. In reply to this, perhaps some one will ask why such drops of sugar, produced

by nature, are no longer found. I answer that the sugar cane now does not become so old. No longer is it left to itself, as it becomes woody and loses its best juice if it stands a year or two. This could even happen to cane growing in the fertile parts of Arabia and in Hindustan, places which are much warmer than these islands of the Indian archipelago.

Moreover, Matthiolus clearly testifies that this was observed in the same way in his day in some countries, where in his commentaries he writes that he had heard from trustworthy eye-witnesses, men who had traveled over the islands of St. Thomas and Madera, that in these places sugar was found condensed in the cane itself, from which it exudes like gum, not unlike that which is called sugar-candy and which is artificially made. But to this Salmasius objects, in his treatise on sugar, published after Solinus. He is strongly of the opinion that the sugar of the ancients was nothing other than the Sackar Mambu, the Tabaxir of the Persians, since they say with full agreement that sugar comes forth from certain reeds. But I cannot accept this statement, since it is well known that sugar cane is considered both as a reed and as a bamboo. And, besides, as I have already said, the stalks of cane, for the most part bending down to the ground and lying on it, were considered as roots. Then, too, never have I read or heard that Tabaxir had in itself any noticeable sweetness. Certainly that which I have found and tasted in Amboina showed no sweetness, and resembled dry starch more than sugar. Besides, we find in the writings of the ancients that people of India made a drink from the roots of sugar cane. Marcus Varro bears witness to this fact in the following verses:

> The Indian cane grows like a rather small tree,
> And from its tough roots a juice is pressed,
> With which sweet honey cannot vie.

With these, Lucanus' verse agrees:

> Who drink the sweet juice from the tender cane.

But no one ever heard of a sweet drinkable juice being secured from bamboo or from any other tree-roots.

Besides, there was another sugar known to the ancients, poorly described and confused with the former. About this, Solinus writes that in the swampy places of India reeds grow so large that from one central joint, cut through the middle and split, a small canoe can be made, in which the Indians navigate large rivers. From the roots of this a sweet honey-like juice is pressed. In my opinion it is thoroughly established from these statements how that Saccar Mamboe which lies in the nodes or hollow grooves and not in the roots of the Indian Mambu or Bamboo and which grows only in the province of Bisnager—for which look up Book 6 in the chapters on reeds—is mistaken for that which is gathered from sugar cane. I think that it was gathered at a time, perhaps, when the stalks of this reed were considered to be roots, for no roots are known from which sugar or syrup can be secured. As an additional proof of the former statement it may be added that Dioscorides attributes to his sugar the same quality which is today seen in ours—it mollifies the stomach and makes the eyes clear, which is the reason why sugar-candy is used today, dissolved in French wine.

In answer to the third question, we can only say that Actuarius was the first to mix sugar with medicinal powders and compounds. From this we can conclude that in those times sugar must have been imported in larger quantities than in the age of Pliny and therefore that the process of making sugar from extracted juice must have been known then.

It should be understood—and this is a warning already given by others—that Saccharum candidum or sugar-candy in no way takes its name from its white color, which in Latin is *candidus*, for we find brown, red and yellow sugar-candy. The name comes from the Greek word κανθος (canthos), which signifies in the Greek of today as well as in various other languages of Europe, a prism, since this sugar is always full of angles like polished adamant or crystal, and for this reason it is fittingly to be called Saccharum canthi.

PLATE LXXIV

In the first drawing the true sugar cane is shown.

The second drawing shows the Rottanga sugar cane, or Tabu Rottang.

P. S.—This Tabu Rottang is scarcely a thumb thick. In its upper half many straight shoots grow out, which have very narrow leaves. These, too, are straight, differing from the leaves of the preceding plant. In fact, they agree with those of Carex. They have a thick midrib, and are the width of the little finger and more than three feet long. Above these shoots are the common leaves, three fingers wide and from four to five feet long. Above these is the usual panicle, which in this species is divided into two or three spikes.

OBSERVATION.

This plant is called simply *Saccharum* in H. Cliffort, p. 26, and *Arundo Saccharifera* in Sloane, Cat. pl. Jam., p. 31, who has almost innumerable authorities this plant. In J. B. and Sam. Dale Pharmac. in 4to, p. 291, it is *Arundo Saccharina.* This author mentions various kinds of sugar juice.

[E. L. C.]

Millets for Fodder on Sugar Estates.*

By C. A. BARBER, C.I.E., Sc.D., F.L.S.

I.

In a recent "Agricultural Note" attention was drawn to the importance of improving fodder supplies on sugar estates, and it was suggested that lessons might be learnt from the indigenous dry farming practised in the East, where with scanty supplies of water and on comparatively poor soil large quantities of food and fodder were habitually grown in the struggle for existence. Millets are the main crop in such dry regions, and it is estimated that one-third of the popu-

* From The International Sugar Journal, Vol. XXII, Nos. 263 and 264, p. 613.


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Tab LXXIV
Fig 1
Fig. 2
Tom V

lation of the world is interested in their cultivation. As an accessory fodder and food crop some form of millet is probably far and away the most economical and productive. But these crops are little known in sugar-growing countries, and it is with the idea of placing the facts dispassionately before planters that the present study has been prepared. After a few remarks on millets in general, it is proposed to deal with one of them as a type and then add notes on the others as occasion may arise.

The millets occupy a very distinct place in tropical agriculture; they are the indigenous dry-land cereals of the tropics, and especially of the Old World. Maize generally takes their place in the New World, but this is essentially a sub-tropical staple; wheat, barley and oats are temperate cereals, and when they penetrate into the tropics they are generally grown on the outskirts, as in Northern India, or in elevated tracts where the climate is not tropical, and then only in the "cold" weather: rice is, of course, tropical, but it is a wet-land crop and the whole methods of its cultivation are entirely special and different from those in crops that are rain-fed.

As is the case with all these crops, millets are occasionally irrigated, especially in tracts with a well-developed agricultural practice, during the dry periods of the year, and very much greater yields are then obtained. But they are essentially rain-fed: they are, all of them, markedly drought resistant, and, maturing quickly, can be grown without irrigation in very dry tracts, where the rains come at only one time of the year: they mature in from three to five months and are thus quite common in regions with less than 20 inches annual rainfall or what are termed semi-arid countries.

Just as wheat penetrates into the tropics and rice into the temperate regions, so the millets sometimes stray outside their tropical limits, and this is the case especially with the Italian or Hungarian millet (*Setaria italica*), which may be found from Europe to the Cape Colony, and may be seen in English botanical gardens in the summer, but this species is more adaptable than the rest.

They all of them have small grains, the giant among them, which will form the subject of this article, *Andropogon Sorghum,* having grains little over one-eighth of an inch in diameter; they may be generally distinguished by their rounded grains and are best known in this country as fowl food or bird seed. In the tropics they form the staple food of the people in the interior, where water is not available for rice growing; they are equally useful for fodder and for cattle and for human consumption; but, as they are only grown for local use, they do not enter largely into export trade.

They form the heart of the dry-land cultivation in Africa, and in Asia are specially developed in India, China, and Japan: there are 40,000,000 acres under millets in India, and the outturn in Japan is given as 35,000,000 bushels every year. They occur where the most primitive and yet intensive dry-farming in the world exists, and their cultivation is therefore associated with old-world simple implements, and they are grown in rotation or as mixtures with pulses, cotton, tobacco and a number of non-irrigated tropical crops.

Sorghum has been selected for detailed study because it is the most important millet: its agricultural needs are greater than some of the smaller forms, but it

can be grown like the rest under unpropitious conditions, while with careful treatment it is capable of a comparatively enormous production as a cereal. It has thus a very wide range of usefulness.

It is chiefly grown for food and fodder, but in America, where it has been introduced from the East, there are forms which are specially adapted for producing sugar syrup and others for making brooms (hence the names "sweet Sorghum" and "broom corn"). This millet can produce great yields under favorable conditions: it is credited with giving "ten times the outturn of most cereals." The grain is an excellent food for man, the stalks are carefully stacked for fodder, and can also be used for fuel if thus required. In the New World it is chiefly grown for fodder, but for grain in the Old World, although it is always used there as a fodder too. The grain is used for cattle and horses, for fattening pigs and for poultry. Sugar is exuded from lesions in the stems and leaves and, as stated, special forms have been developed which produce excellent syrups from the juicy stems.

There is considerable doubt as to the place of origin of Sorghum: it has many wild relatives and is widely scattered in the indigenous cultivation of Africa, India and China. Most probably it was first used in tropical Africa, was thence passed through Egypt to India, and from India to China and Japan; its introduction into the New World is comparatively recent, possibly through the slaves from Africa, as these are known to have brought many of their home plants with them. In India alone have we accurate information as to its distribution: the average acreage for the past seven years was 21,166,166. Bombay has 7,000,000, Madras 5.000,0000, the Central Provinces 4,000,000; thus the Peninsula has two-thirds of the whole, and this emphasizes its tropical nature. In North India its substitutes are maize, wheat and another millet, *Pennisetum typhoideum.*

Botanically, it is a tufted grass, but as grown the stalks are few: this is of advantage as ensuring even ripening, a matter of great importance at the harvest. It is the largest cereal. Because of the mode of growth, usually stems with single heads, there is little separation between the branching and flowering stages which characterize the growth of all grasses. The heads of panicles vary greatly in size and form. When grown for grain, the close round or oval head is preferred, but the open panicle when it is purely a fodder crop. The "irungu cholams" of South India appear to be ideal as a fodder crop, and seed should be obtainable of all varieties by application to the Department of Agriculture in Madras. There are sometimes curious forms, such as the one in which the flower stalk bends down so that the head hangs downwards: it is difficult to trace the origin of this, but it is of advantage as a protection against birds, as they can obtain no foothold. There are two kinds of flowers, sessile which are fertile, and stalked which are sterile. The flowers are proterogynous, that is, the female organs ripen first; this necessitates cross-pollination and the plant is wind-fertilized, a fact which is of some importance as regards the crop. If, for instance, heavy rains occur at the time of flowering, the yield will be very seriously affected. This is a point to be borne in mind with all the millets, and it influences some of the others to a greater extent than Sorghum. The grains are large for a millet, as already noted. In Bombay there is a variety which has

double grains. The glumes, or chaffy outer scales of the grain, vary greatly in color, so that we have black, brown, red, yellow, white and spotted grains, by which differences many of the varieties are most easily recognized. The leaves are broad, like those of maize, two-ranked, wavy edged, with hyaline ciliated ligule, the little membranous protrusion at the junction of leaf-sheath and leaf. The roots are surface feeding, varying in depth according to soil and moisture, i. e., as to whether it is grown as a wet or dry crop. Besides the ordinary soil roots, it possesses a series of aerial roots, which spring from the lower joints above ground; these roots are strong and bend outwards and downwards into the soil where they branch, thus holding the tall plant erect after the manner of tent ropes. A true classification is at present impossible, because of the mixed nature of the fields where crossing has proceeded for ages unchecked. The color of the glumes is a useful character, dry, pithy and juicy, sweet stalks, habit and especially shape of the head, agricultural requirements as to soil and water, length of growing period, drought resistance and so on, all are of assistance in determining the different kinds. It is interesting in this connection to connect the kinds of Sorghum grown with the local races of people: when a native migrates, he takes a few of his own seeds with him, for he finds that the kinds met with do not suit his palate or digestion, and the appearance of a strange form of Sorghum in the fields will often lead to the discovery that such a migration has taken place.

As to environment, all will depend on the character of the rains. Sorghum often experiences conditions which would destroy ordinary cereals such as maize. There must be free drainage, for it will not bear any standing water. Here maize has the advantage, for the writer has seen the crop reaped from boats, where the plants at crop time were under six feet of water. Sorghum has a remarkable power, which is not shared by maize, of remaining quiescent during periods of drought and immediately recovering with a shower of rain. Experiments made in the Great Central Plains region of the United States have shown that Sorghum and bullrush millet require less rain to produce a ton of hay than any other cereal tried. The cultivation of Sorghum is often a triumph of man over nature, both in North Africa and in the east, by taking advantage of casual showers which would be of no use to any other crop but a millet. The Tamil proverb runs: "if you have little to eat, sow cholam."

The preparation of the land and cultivation are simplicity itself. Sorghum can be grown on very poor land, but of course the yield will be affected in such a large plant: it grows best in deep red loam, where a height of 12-16 feet is not uncommon, and black soil also seems to suit it very well. Such manure as is available is heaped in the dry weather and the land is cleared of deep-rooting grasses: on the first showers the land is plowed repeatedly by the simple Indian plows, and two or three weedings are needed and, if planted in rows, harrowings to keep the surface mulch of soil. There may be all stages from the most primitive to the most advanced dry-farming.

Sowing varies greatly according to conditions, from two to three seeds in a shallow hole, broadcasting against a basket, or drilling. The rate varies according to whether it is grown for grain or green fodder, as well as the kind of soil,

etc. Four to ten times as much seed is sown for green fodder, as then the stems are as close as in a field of wheat: when grown for grain the plants are thinned when 6-8 inches high, so that they are about a foot apart each way: 10-15 pounds per acre should be sufficient for a crop intended for grain and straw, 40-100 pounds when it is intended for green fodder. Sorghum is often sown as a mixed crop with legumes, and the most various mixtures are in vogue in India. To give an example: five crops are sometimes sown together: cucumbers will ripen in six weeks, cow peas in three months, Sorghum in four months, red grass (pigeon pea or *Cajanus indicus*) in seven months and, when the latter is reaped, the whole field will be covered by it and no trace left that any other crop has been grown. The time of sowing depends on the incidence of the rains, not heavy rains, but occasional showers: this is extremely important in dry tracts, and is forcibly expressed by another Tamil proverb, "if the time of sowing is missed cholam will not grow if it is sown on a dunghill."

The best method of reaping is to cut the field and lay the plants spread out on the ground for four days, then raise them in cocks for a month to allow the immature grains to harden; then thresh and heap the straw into great ricks. This straw will keep for the best part of a year and provides good fodder for cattle. If raised for green fodder it may be cut as required, the best food value being obtained when the flowers are beginning to set seed: or the whole may be cut and stacked in a rick, after a little wilting, the stalks being laid with the heads inwards.

The yield depends, of course, on conditions, and there may be from 100 to 500 to 1500 pounds of grain; if grown for fodder anything up to 25 tons may be harvested. It is a common practice to ratoon the crop for a time, as the stalks left will send out many shoots. But this requires some care and should not be attempted by novices. The young foliage if poorly grown develops a deadly poison, but this does not occur if there are rains or the soil is moist and the growth free. Such ratooned Sorghum forms excellent grazing for the cattle.

The crop has its own diseases and pests, which are far too numerous even to catalogue in detail. All insects, all birds, many beasts, together with fungi and even small parasitic flowering plants. In growing crops, aphids, mites, ear moths, stem and shoot borers, smuts, rusts, protozoa, moulds: also seeds germinating on the plant in wet weather, low-lying places and alkaline spots should be guarded against: as stored grain the usual grain pests will also be met with. There is no space to speak of the value of the grain as food, but it may be mentioned that both grain and flour keep well because of the comparatively little water and oil that they contain. Bread cannot be made from it, as it will not form loaves, but as cakes and porridge it is excellent, once the somewhat peculiar flavor is mastered.

II. THE LESSER MILLETS.

After the remarks on millets in general in the two preceding papers (I.S.J., 1920, pp. 493 and 613), and the somewhat full treatment of the great millet, Sorghum, as a type, it would entail a good deal of repetition to write at all fully about the smaller species which make up the class. In the following, the three

chief ones have been selected for a more complete study, and it may be assumed that the rest, gradually tailing off into wild grasses only used as food in times of famine, but often planted as fodder for cattle, may merely be recorded, although it is impossible to give such a list in detail. Taking the whole series, from the great millet to the wild grasses, there is a regular diminution in the amount of care that they require in cultivation, this being, of course, coupled with a like decrease in the value and quantity of the crop, both in grain and fodder obtained. There is thus a wide field for selection, according to the purpose held in view by planters inclined to give them a trial, and the character of the land to be planted with them. * * *

Bulrush Millet (*Pennisetum typhoideum*).

This plant stands in some sort half-way between Sorghum and the lesser millets. It resembles Sorghum in certain respects. It has erect solid stems of some thickness and reaches a height of five to six feet: at the base aerial roots are met with which act, as in Sorghum, as supports for the plant, for it must be remembered that all of the millets are shallow-rooted and the taller ones are liable to be overturned by sudden gusts of wind: bulrush millet furthermore favors the lightest of soils. Like Sorghum, it is proterogynous, the female flowers in each spike being receptive before the pollen is scattered: and thus this crop is wind-pollinated and is liable to injury by rain showers at the time of flowering, indeed more so than in Sorghum. Heavy rain showers are specially harmful to bulrush millet at all times, whether by drowning the young seedlings, turning the leaves yellow when in active growth, in the flowering season, or by causing the grains to sprout and spoil in the head at maturity. But it differs from Sorghum in the form of the ear, which, as a long, smooth cylinder, bears a close resemblance to that of the bulrush, after which it is usually named: it tillers much more freely, so that a number of ears are borne on the same stool, and the leaves are much narrower.

The plant is a typical catch crop, matures very quickly and requires considerably less manure, a lighter soil and less cultivation than Sorghum. It is widely distributed over eastern Asia and the African continent, from India to China and Japan, and from Tripoli, where as "Shessab" it is recommended as a valuable irrigated fodder crop, and Egypt, where it is grown for its grain, to the Transvaal, which has an excellent variety, excelling those of India in vigor, rapidity of growth, length of spike and size of grain. In India there are many varieties, differing in quality and quantity of straw to grain, character of grain, and the ease of clearing it from the husk, size of spike, etc., and in one part the ear is provided with long awns or bristles which protect it from the inroads of birds, the chief enemy of the crop. While the smaller birds perch on the ear and go through the hidden stores of grain methodically, the larger ones, such as the parrots, which sometimes descend in immense numbers on the fields, cut the ears right off and fly to some tree, where they pull out half the grain and waste the rest.

The straw is not usually liked by cattle, although it does not appear to be deficient in feeding value. The grain is nutritious and heating, so that it is said

to be a favorite in North India in the colder part of the year. In whole tracts it is the main cereal of consumption, and there are some 15,000,000 acres of it in India, where alone the returns are available. The seed rate varies from 3 to 10 pounds per acre according to the character of the soil, but when, as is often the case, it is sown as a mixed crop (for instance with ground nut, an excellent combination) a good deal less is required. The yield varies enormously according to conditions: an average crop will be 300 pounds to the acre, but as much as 1000 pounds may be obtained under favorable conditions as a dry-land crop and double that quantity when irrigated.

ITALIAN MILLET (*Setaria italica*).

This is a very graceful millet. * * * According to some authorities, it is the most important millet cultivated, but one doubts whether the dominating character of Sorghum has been realized by these. Cultivation of Setaria is known to be very ancient, as it is one of the sacred crops of the Chinese, recorded as planted with much ceremony by the Emperor and his courtiers nearly 3000 years B. C. It is impossible to assign a native country to so old a cultivated plant, but it has been found in the Swiss lake dwellings, showing that it had a wide distribution in prehistoric times. At present its greatest development appears to be in China, Japan and India, but it is world-wide in its distribution, being used chiefly as grain in the three countries mentioned above and more as a fodder in Europe, Canada, the United States and South Africa, where it is known as "Boer manna."

In Madras there are about 2,000,000 acres, and it is often planted in alternate rows with cotton and other non-cereal crops. The seed rate is given as 5 to 6 pounds per acre if irrigated, half of that quantity if on dry land and of course still less if grown as a mixed crop. The yield as a dry-land crop reaches 600 pounds of grain per acre, and if irrigated 1000 pounds, with 1000 to 2000 pounds of straw. There are, as in bulrush millet, many varieties, chiefly in the amount of branching and thickness of its rope-like, nodding ears and in the size and color of its grain. As in other millets it is eaten as unleavened cakes or porridge.

RAGI (*Eleusine coracana*).

This millet forms a class by itself, and has many characteristic wild relatives: it always strikes one as a wonder, therefore, that it has such valuable properties. As the Indian flora contains a number of these wild relatives it is usually considered to be indigenous to that country. It is a moderately tall, tufted grass, with the ear divided into a number of radiating branches, after the manner of a bird's foot. It is cultivated as a cereal over India and Japan and parts of Africa, but there is not much literature available on the subject. It is largely grown in India, in the south as an important irrigated crop, but elsewhere rainfed, both in the plains and on the hills at the onset of the monsoon. Its cultivation in South India is very carefully attended to, the seedlings being raised in special, well-treated nurseries and then transplanted to land constantly kept moist, in these respects resembling paddy. About 2 pounds of seed will plant up an acre of land: this may seem a very small quantity, but it is very pro-

ductive and the seeds are very small, there being 157,500 to the pound. The yield is 2000-3000 pounds per acre with up to 8000 pounds of straw. As a wet crop it is invariably planted pure, but on dry land it is often mixed with pulses, oilseeds and other crops. There are several varieties, two main groups being distinguished by having the radiating branches of the ear spread out or closed in, after the manner of the human hand: in the form figured the ear is open. It is a very hardy crop and will grow where scarcely any other can be planted: the wet land forms are noted as specially resistant to alkali and salt, and ragi is often grown as a first crop on reclaimed land before it becomes fit for paddy.

Harvesting is difficult because of its habit of branching high up and thus bearing ears of different ages; the sickle is used or the ears are merely taken off by hand, and there have to be several reapings. It is supposed to be the most prolific of the grain class, and a record has been made of a single seed which gave rise to 56 upright stalks with 8100 grains. About 25,000,000 hundredweights are computed to be consumed every year in India alone. The porridge made from it is not unpalatable, especially when mixed with coconut milk, as the writer can testify, having frequently used it as a welcome change from oatmeal in the hot weather. It is specially valued by all engaged in heavy manual toil and is the general regimen in jails, as it is a very strengthening food. On one occasion, when the writer's supply of American flour gave out far from the source of supply, he was compelled for a couple of weeks to feed on ragi porridge and cakes, and he noted that he was able to do the most surprising marches without excessive fatigue. Ragi straw, which is fed half green, is considered a very good fodder.

The following analyses of the grain and straw of millets, paddy, and wheat, which have been taken out of a useful little Madras publication, R. C. Wood, "Notebook of Agricultural Facts and Figures," may be of interest to readers. The writer is indebted to the same publication for most of the figures of seed rate and yields.

	Water	Proteid	Oil or Fat	Carbo-hydrate	Crude Fiber	Ash	Nutritive Ratio[1]
Grain:							
Sorghum....	10.71	9.71	3.69	72.38	1.54	2.05	1 : 8.3
Ragi........	11.29	9.44	4.93	60.13	6.56	7.65	1 : 7.5
Varagu[2]....	8.84	8.04	4.57	65.20	7.39	5.95	1 : 9.5
Kambu[3].....	8.77	9.52	5.33	73.52	0.78	2.08	1 : 9.0
Paddy......	12.55	6.35	2.14	65.29	7.84	5.83	1 : 11.0
Wheat......	13.33	9.74	1.76	70.18	2.10	2.98	1 : 7.7
Straw:							
Sorghum....	8.70	2.10	1.50	39.67	39.77	8.24	....
Ragi........	14.16	1.94	0.62	49.11	28.93	5.24	....
Varagu.....	8.71	1.97	2.51	47.92	28.84	10.05	1 : 26.8
Kambu.....	7.07	1.94	1.33	43.99	37.63	8.04	1 : 23.5
Paddy......	11.04	2.70	1.02	40.84	29.23	15.17	....
Wheat......	8.71	3.01	0.98	37.93	35.69	13.93	1 : 13.0

[1] Proportion of nitrogenous to non-nitrogenous constituents of the food.
[2] *Paspalum scrobiculatum.*
[3] *Pennisetum typhoidum.*

[J. A. V.]

The Vitality of Cane Seed.*

The seed of the sugar cane is, to all intents and purposes, similar to that of wheat, barley, and many cultivated and wild members of the grass family. It is very small, but with a little care it may be readily obtained in the following manner: Cut the arrow as soon as the feathery florets begin to fly away in the breeze—a sign that the arrow is ripe—detach the branchlets, and crumple up the mass in the hand and place it in a linen bag. After about a week, carefully rub the mass between the fingers on to a large, clean piece of paper, when the small seeds can be easily made out, inside the transparent chaffy scales, as short dark lines about 1.5 mm. long and 0.5 mm. broad. The seed of each variety or individual arrow may be preserved in a small corked bottle and kept in a dry place. The vitality of cane seed is usually considered to be very low, but this is probably not the case, considering its minute size, if ordinary care is taken to protect it from drying up.

In order to test this vitality, the seed may be sown in earthenware pans, a convenient size of which is one foot across and three inches deep. These pans should be filled with a mixture of equal parts of river sand and powdered horse manure. The latter should be completely freed from grass seeds by watering and exposing in a thin layer. When the grasses have germinated and been duly removed, the manure may be dried again and stored for future use. It is not necessary to take the trouble to sow definite numbers of seeds in the pans: it is doubtful indeed whether, by separating them from their enclosing scales, they may not be injured or dried up. What we want to know is the length of time after collection that the seeds still retain their germinating capacity, and for this purpose it will suffice to sow equal parts by weight of the arrow mass, at intervals of a fortnight or month. But the arrows must be broken up into quite small tufts to remove the thicker stalks, and also well mixed, because the number of seeds in the upper and lower parts of the arrow differs considerably. Weigh out a definite quantity of the mixed mass and spread it evenly over the surface of the pan, then water it lightly from a fine rose-can, and the fluffy hairs will adhere to the soil and not be blown away with the breeze; afterwards, keep the pans in full sunshine and water in a similar manner twice daily.

The first germinations take place within three or four days of sowing, and the tiny plants are removed day by day as they appear, a record being kept of all such removals. The sowings should be continued at intervals until no more germinations take place. That the vitality of the seed is often considerable may be seen from the accompanying table, which gives the results of an experiment with monthly sowings made at the Cane-breeding Station at Coimbatore in 1914-15.[1]

* From The International Sugar Journal, Vol. XXII, No. 260, p. 435.

[1] C. A. Barber, Studies in Indian Sugar Canes, No. 2. Memoirs of the Department of Agriculture in India, Botanical Series, VIII, 3, 1916, p. 127.

Variety	Date of Collection	Germination Test	Feb. 1	Mar. 1	Apr. 1	June 1	July 1	Aug. 1
Madras No. 2....	Dec. 9, 1914	500	500	300	200	100	20	0
Madras No. 6....	Dec. 15, 1914	500	500	300	200	100	20	0
Saretha	Dec. 14, 1914	500	500	500	300	200	40	0
Java	Jan. 4, 1915	500	500	300	100	50	0	0
B 208	Jan. 5, 1915	500	500	300	less than 100	12	5	0
Striped Mauritius	Jan. 5, 1915	200	200	100	50	12	0	0

Equal quantities of pounded arrow were sown in the first five, a less quantity being available in Striped Mauritius.

The arrows were collected from December 9th to January 4th and tested for germination before the experimental sowings commenced. Sowings were then made on the first of each month, with the exception of May, until August, when, no germinations resulting, it was assumed that the seeds remaining had died. Some of the cane seed was capable of germination seven months after collection. Saretha and the two Madras seedlings showed most vitality and the thick tropical canes least, but even in the latter much of the seed retained its life for four months. From this it appears that it should be quite easy to send cane seed from one end of the world to the other without injury, probably best in the arrow itself.

[J. A. V.]

On One-Bud Planting.*

A worker has recently claimed that a greater mass of canes to the acre can be obtained by planting only one bud of each set and placing the set so that this bud faces upwards.[1] He goes a step further. He also asserts that, as the result of experiment, by removing all the lateral branches and allowing only the mother cane to grow, a much more uniform crop can be obtained of thick canes which all ripen together, an obvious advantage in harvesting. But we confess that we are not convinced as to the soundness of this practice in the field. Let alone the great amount of troublesome work in planting, the number of sets must be enormously increased if each one is only allowed to produce one cane. There may perhaps be something to be said for allowing only one bud to grow from each set, for by this means we should, theoretically, be able to obtain a set of plants unhampered in their growth by a struggle with near neighbors. Healthier plants will undoubtedly be produced. In planting single-bud sets a more careful scrutiny of the planted material will be necessary, and it is well known that many diseases are propagated in the fields by careless selection of the plant cut-

* From the International Sugar Journal, Vol. XXII, No. 260, p. 436.

[1] Kulkarni, M. L., Experiments in planting Sugar Cane Sets with Single Eye-buds, etc. Agricultural Journal of India, Special Science Congress Number, 1918.

tings. It has recently been demonstrated that, by planting only one seedling of paddy (the rice plant) in each hole, instead of the time-honored bunch of seedlings, a better outturn of rice is frequently obtained; but with the allied sugar cane we must reserve our opinion, as it is a matter which the practical planter must settle for himself. The subject has been introduced here, merely to indicate that, in the working of the fields, there is plenty of room for a study of the underground branching system of the cane plant, and that time-honored customs need not of necessity always be the best. There is any amount of scope here and elsewhere for the thoughtful planter to conduct simple experiments of this nature.

[J. A. V.]

SUGAR PRICES FOR THE MONTH

Ended March 15, 1921.

	96° Centrifugals		Beets	
	Per Lb.	Per Ton.	Per Lb.	Per Ton.
Feb. 16, 1921	5.77¢	$115.40	No quotation.	
" 18	5.64	112.80		
" 23	5.77	115.40		
" 28	5.765	115.30		
Mar. 3	5.77	115.40		
" 4	5.765	115.30		
" 7	5.825	116.50		
" 8	5.96	119.20		
" 9	6.01	120.20		
" 11	6.02	120.40		

[D. A. M.]

THE HAWAIIAN PLANTERS' RECORD

Volume XXIV. MAY, 1921 Number 5

A monthly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

Fiji Disease Gains Ground

Fiji disease has gained entrance to the Philippine Islands and is already established in several localities on Mindoro and Luzon. It has not been found on Negros up to the present time, and the Government is endeavoring to keep it out of that island by a strict quarantine.

The occurrence of Fiji disease in the Philippines greatly increases the chances of its eventually finding its way to Hawaii. We may rely upon our plant inspection service to intercept all canes coming by the usual routes; but there are unusual routes by which canes may arrive, and over these we can exercise no control.

It behooves us, therefore, to keep a sharp lookout for this disease, so that if it does reach our cane fields we shall detect it before it spreads to any extent, and so render its elimination possible.

Descriptions of Fiji disease sufficient for diagnosis may be found in early numbers of this magazine,* but in order to renew our impressions of this malady we are printing in this issue a brief description in which we combine the essential statements of our former articles and add some additional material.

Native Canes May Come Back

Some months ago, Messrs. Caum and Moir began a critical study of native canes. The necessity for this research was created by the keen interest being manifested in bud sports. Odd stools of cane are frequently found in fields of standard canes, and there is a tendency to view all such stools as bud sports of the standard variety which surrounds them. The majority of such odd stools, however, arise through the chance introduction of a cutting of some little known variety, and native canes are the most frequent interlopers of this sort. If we are going to correctly judge all such odd stools and recognize a bud sport when it does appear we must know all of the canes that can possibly gain entrance to our cultures.

*** Planters' Record 3:200-202, and 4:330-332.**

In their studies of the native canes Caum and Moir have brought to light some startling facts which may prove of far-reaching importance to the local sugar industry.

They have demonstrated that Striped Tip, Yellow Tip, and Yellow Bamboo are in reality native canes. These facts suggest a very interesting line of reasoning and a very promising line of experimentation. The canes mentioned have all made good records under adverse conditions where the cultivation of the better known varieties has proven unprofitable. Thus in Hamakua and Kohala, Striped and Yellow Tip have no equals as drought-resisting canes, and as high-land canes their excellence is recognized along the entire windward coast of Hawaii, while in the Pahala district Yellow Bamboo has been a successful competitor of Lahaina and Yellow Caledonia on fields of moderate to high elevation.

Does this not indicate that these native canes possess as inherent qualities certain sturdy characters which we are particularly anxious to bring out in some good canes at the present time? Drought resistance is a virtue much to be desired in any cane, while a variety suited to culture at high elevations is one of the immediate and pressing needs of the industry. Would it not be advisable, therefore, to test out all the available native canes in high-land nurseries; and at the same time employ the better varieties in our cane-breeding experiments?

Stubble Shaving.

Onomea Sugar Co. Experiment No. 10, 1921 Crop.*

SUMMARY.

The purpose of this experiment is to determine the value of stubble shaving towards increasing the yield of a field. The stubble shaving was accomplished by means of the implement modified from the Avery stool shaver by Mr. Silver.**

The cane involved was third ratoon, long. The stubble shaving was done on July 18, 1919, after which all plots were given uniform treatment by the plantation.

The result shows no increased yield of cane due to the stubble shaving. Slightly poorer juices from the shaved cane cause a slightly poorer yield of sugar than from the unshaved cane. Until we have more definite information regarding the effect of stubble shaving on the quality of the juices, we would be inclined to doubt the apparent loss of sugar due to stubble shaving. Following are the yields obtained:

* Experiment planned by W. P. Alexander ~~and~~ J. A. Verret.
Experiment laid out by W. L. S. Williams.

** See Record, Vol. XXI, p. 8.

Treatment	Yield—Tons per Acre		
	Cane	Q. R.	Sugar
No stubble shaving	41.5	7.44	5.58
Stubble shaving	41.6	7.79	5.34

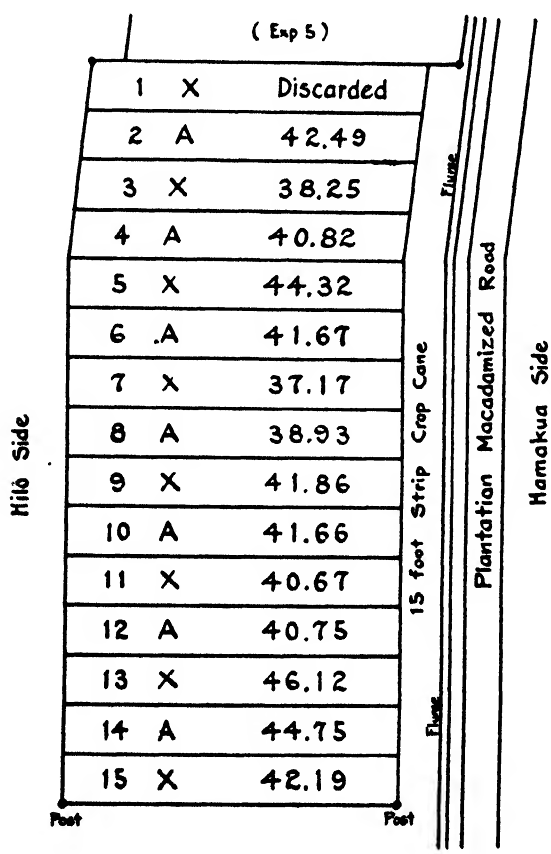
The following excerpts are taken from Mr. Williams' notes on the condition of the field at time of stubble shaving:

"This section of the field was not off-barred in 1917, but was hilled up quite high in 1918. Before harvesting the trash was burned and a second burning was applied before shaving the stubble. * * * The machine shaves from 2 to 3 inches from the top of the stools, cutting down all stumps and secondary growth (suckers). Sometimes high stools cause jamming of the machine, and delays, but this time serves to rest mules."

STUBBLE SHAVING

ONOMEA SUGAR CO. EXP. 10, 1921 CROP

Field 35.



Summary of Results

Plots	Treatment	Yields Per Acre		
		Cane	Q.R.	Sugar
A	Stubble Shaving	41.6	7.79	5.34
X	No Stubble Shaving	41.5	7.44	5.58

DETAILS OF EXPERIMENT.

Object:

To determine the value of stubble shaving with implement modified from the Avery stool shaver by Mr. Wm. Silver.

Location:

Field 35, makai of Experiment No. 5.

Crop:

Yellow Caledonia, third ratoon, long.

Layout:

No. plots: 15.

Size of plots: 1/10 acre each, consisting of 6 rows each 5.94 feet wide and 122.2 feet long.

Plan:

X plots—no stubble shaving.

A plots—stubble shaved.

Fertilization uniform to all plots and applied by the plantation.

Progress of Experiment:

July 18, 1919—Stubble shaved.

August 8, 1919—Fertilized 400 pounds B6 per acre.

November 20, 1919—Fertilized 400 pounds B6 per acre.

March 3, 1921—Experiment harvested by W. L. S. Williams.

R. S. T.

Lime Versus No Lime.

HILO SUGAR COMPANY EXPERIMENT No. 18,* 1921 CROP.

This is an experiment to determine the value of lime and coral sand on acid soils. Comparison is made between 2000 pounds burned lime, 8000 pounds coral sand, 12,000 pounds burned lime, and nothing. The cane involved is Yellow Caledonia, fourth ratoons, long. The field was first off-barred, then the lime and sand applied in the kuakua. After applying, mule cultivators passed twice along each line, thoroughly mixing the lime and soil. All plots received uniform fertilization by the plantation.

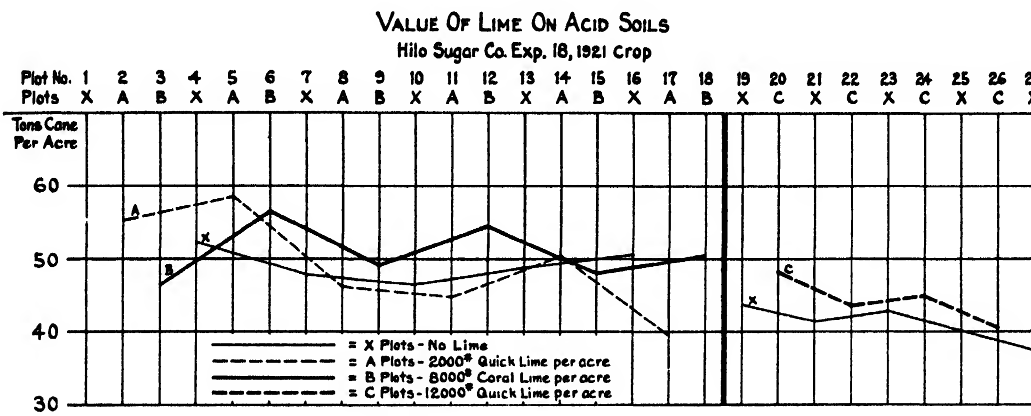
The results show that 12,000 pounds of lime produced a gain of 3.41 tons cane, while the 8000 pounds of sand and the 2000 pounds of lime showed practically no gain. The following tabulation shows the yields for the different treatments compared with the adjoining untreated plots:

Plot	Treatment	Tons Cane per Acre	Gain or Loss over Adjoining X Plots: Tons Cane per Acre
X (A & B)	0	49.26	0
A	2,000 lbs. lime	49.33	+ .07
B	8,000 lbs. sand	50.99	+ .73
X (C)	0	41.24	0
C	12,000 lbs. lime	44.65	+ 3.41

* Experiment planned by J. A. Verret and W. P. Alexander.
Experiment laid out by W. P. Alexander.
Experiment harvested by W. L. S. Williams.

The accompanying map shows the relative positions of the plots and also the individual plot yields.

An examination of the individual plot yields shows that the A, B, and adjacent X plots give considerably larger yields than do the C plots and their adjacent X plots, but this larger yield is due to some other factor than lime. In the case of the A, B, and adjacent X plots the yields are so irregular that no definite benefit from lime is noticeable, but in the case of the C plots and their adjacent X plots the difference between the C and X plots, though small, is consistent. This is clearly shown in the following curves:



This experimental area is to be plowed and planted and the experiment repeated on plant cane, using the same plots to note any residual effect the lime and sand may have on subsequent crops.

DETAILS OF EXPERIMENT.

Object:

To determine the value of applying lime and coral sand, comparing:

1. No lime or sand,
2. 2000 pounds burned lime,
3. 8000 pounds coral sand,
4. 12,000 pounds burned lime.

Location:

Field 20, along Amauula macadam road.

Crop:

Yellow Caledonia, fourth ratoons, long.

Layout:

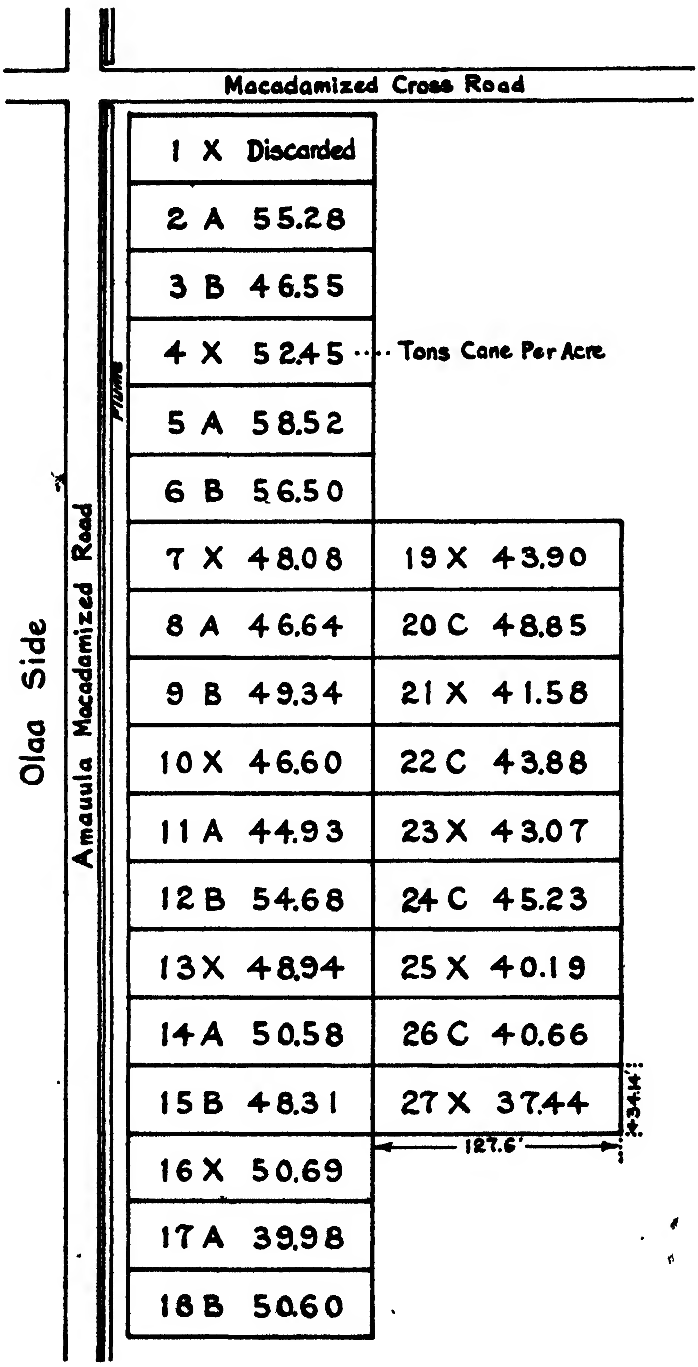
No. of plots: 27.

Size of plots: 1/10 acre each, consisting of six rows, each 5.69'x 127.6'. Rows 1 and 6 in each plot are guard rows to be discarded on harvesting, and rows 2, 3, 4, and 5 harvested as experiment.

VALUE OF LIME ON ACID SOILS

Hilo Sugar Co. Exp. #18, 1921 Crop

Field 30.



Summary of Results

Plots	No. of Plots	Treatment	Tons Cane Per Acre	Gain or Loss Over X Plots
X	6	No Lime	49.26	
A	6	2000# Quick Lime p.a.	49.33	+0.07
B	6	8000# Coral Lime p.a.	50.99	+1.73
X	5	Nothing	41.24	
C	4	12000# Quick Lime p.a.	44.65	+3.41

Plan:

Plots	No. of Plots	Treatment	Pounds per Acre
X	11	0	0
A	6	Burned lime	2,000
B	6	Coral sand	8,000
C	4	Burned lime	12,000

NOTE:—Analysis of top 10 inches of soil shows 5 tons of lime (CaO) are necessary to neutralize this soil.

Fertilization:

Uniform to all plots and to be applied by plantation as to surrounding field.

PROGRESS.

June 12, 1919—Offbarred.
June 14, 1919—Lime and sand applied.
July 2, 1919—Fertilized, 250 pounds C_2.
September 8, 1919—Fertilized, 375 pounds B_6.
January 20, 1921—Experiment harvested by W. L. S. Williams.

R. S. T.

Fertilizer—Forms of Nitrogen.

Grove Farm Experiment No. 1, 1921 Crop.*

In this experiment comparison is made between (A) inorganic nitrogen in several doses, (B) organic nitrogen in one dose, with a small spring dressing of nitrate of soda, and (C) no nitrogen, on second ratoons, long.

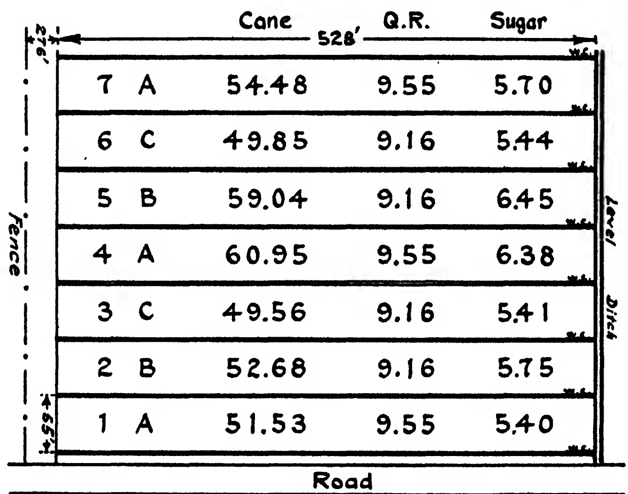
The cane yields of the organic and inorganic applications are identical, but better juices from the organic nitrogen give the sugar yields from those plots as 0.27 ton more than from the inorganic fertilization. It should be noted that the March and May fertilizations of the inorganic plots were combined and applied June first as nitrate of soda, making an application of 435 pounds nitrate of soda. This large application of fertilizer rather late in the season is probably responsible for the poor juices of these plots, and consequently for the apparently poorer yield from the inorganic nitrogen. The following tabulation shows the treatment and yields for this crop:

* Experiment originally planned by L. D. Larsen.

Plot	Fertilization in Pounds Nitrogen per Acre			Total Lbs. Nitrogen per Acre	Yields—Tons per Acre		
	Sept. 30, 1919	Feb. 6, 1920	June 1, 1920		Cane	Q. R.	Sugar
A (Inorg.)	36.75	36.75	67.50	141	55.65	9.55	5.83
B (Org.)	110.25	0	30.75	141	55.86	9.16	6.10
C (0)	0	0	0	0	49.70	9.16	5.43

Comparing now the yields of the organic and inorganic plots for the past three crops, we find that in plant cane the inorganic fertilizer gave considerably larger yields in both cane and sugar; in the first ratoons the yields in both cane

FORMS OF NITROGEN
GROVE FARM EXP. 1, 1921 CROP
Field 4.



Summary of Results

Plots	Treatment	Yields – Tons Per Acre		
		Cane	Q. R.	Sugar
A	Inorganic	55.65	9.55	5.85
B	Organic	55.85	9.16	6.10
C	0	49.70	9.16	5.43

and sugar were practically identical for both forms of nitrogen, and the total yield of cane and sugar for the three crops shows the inorganic nitrogen producing 6.09 tons cane or 0.59 ton sugar more than the organic nitrogen. The following tabulation shows the yields for each of the three crops and also the total yield of each treatment for the three crops:

Forms of Nitrogen	1917			1919			1921			Total for 3 Crops		
	Cane	Q. R.	Sug.	Cane	Q. R.	Sug.	Cane	Q. R.	Sug.	Cane	Q. R.	Sug.
Inorganic ...	50.89	8.57	5.94	36.5	8.25	4.42	55.65	9.55	5.83	143.04	8.83	16.19
Organic	44.19	8.80	5.02	36.9	8.20	4.48	55.86	9.16	6.10	136.95	8.77	15.60
None	49.37	9.13	5.41	36.2	7.9[illegible]	4.57	49.70	9.16	5.43	135.27	8.78	15.41

As originally laid out for the plant crop, this experiment was designed to compare the Grove Farm method of fertilization with that generally recommended by the Experiment Station. The former practice was one application of organic nitrogen plowed into the soil before planting, while the latter practice was to apply nitrogen in three applications, during the growth of the crop, as soluble salts. After the plant crop the experiment was continued to compare organic and inorganic nitrogen.

The conclusion to be drawn from this experiment after harvesting three crops is that inorganic nitrcgen is fully as effective as organic. As the former is the cheaper per unit, it would appear to be the preferable form.

Another phase of this experiment deserving consideration is the slight response of cane to nitrogenous fertilizer. During the plant and first ratoons, the yield of the fertilized and unfertilized plots, in both cane and sugar, was practically identical. In the second ratoon crop, after six years without the addition of nitrogen, the unfertilized plots show a loss in both cane and sugar. The following tabulation compares the average yield of all the fertilized and unfertilized plots for each of three crops:

	1917		1919		1921		Total Yield per Acre for 3 Crops	
	Cane	Sug.	Cane	Sug.	Cane	Sug.	Cane	Sug.
Fertilizer	47.54	5.48	36.7	4.45	55.75	5.96	139.99	15.89
No Fertilizer	49.37	5.41	36.2	4.57	49.70	5.43	135.27	15.41

Following are the average juice analyses for each treatment for the last crop:

Plot	Treatment	Brix	Pol.	Purity	Q. R.
A	Inorganic	17.30	14.26	82.43	9.55
B	Organic	17.66	14.76	83.58	9.16
C	No Nitrogen .	17.38	14.70	84.58	9.16

DETAILS OF EXPERIMENT.

Object:

To compare organic nitrogen with nitrogen from inorganic salts.

Location:

Field 4.

Crop:

Yellow Caledonia, second ratoons, long.

Layout:

No. of plots: 7.

Size of plots: ⅜ acre (528'x 55'). Plots are separated from each other by water-courses which are straight and parallel. Cane lines are irregular.

Plan:

Plot	No. Plots	Form Nitrogen	Fertilization in Pounds Nitrogen per Acre				Total Lbs. N.
			Sept., '19	Jan., '20	Mar., '20	May, '20	
A	3	Inorganic	36.75	36.75	36.75	30.75	141
B	2	Organic	110.25	0	0	30.75	141
C	2	None	0	0	0	0	0

Inorganic nitrogen to be supplied by fertilizer mixture containing 11% N. (5% nitrate, 5% sulfate, 1% organic) and 9% phosphoric acid.

Organic nitrogen to be supplied by dried blood containing 12% N.

NOTE:—This experiment is a continuation of Experiment 1, 1917 and 1919 crops, which compares the Grove Farm practice of using organic nitrogen with the ordinary practice of using inorganic salts.

PROGRESS OF EXPERIMENT.

June 9-12, 1919—Last crop harvested.

September 6, 1919—This field was cut back. Since harvesting it has been offbarred, hilled up, and irrigated twice.

September 30, 1919—First fertilization as per schedule.

February 6, 1920—Second fertilization as per schedule.

June 1, 1920—Third and fourth fertilizations combined and applied today as N. S.

March 3, 1920—Experiment harvested by J. H. Midkiff. Calculations of cane yields and juice analysis made by A. H. Case.

R. S. T.

Native Canes on Molokai.*

By E. L. Caum and W. W. G. Moir.

In the course of our travels on Molokai, seven varieties of native canes new to us were found, names for four of them being obtained. In addition, further evidence that Striped Tip and Yellow Tip are native canes was obtained.

*From a report on an expedition to Molokai in search of native varieties of sugar cane.

Native cane in Kamakaipo Valley, Molokai.

On a trip to Kamakaipo Valley, on the west side of Molokai, a variety of cane, which is probably Ko Oliana, was found growing among the rocks under semi-arid conditions. In spite of a three years' drought that had burned the ranch pasturage, the cane had persisted, and when found had sticks three to four feet in length, with joints two to three inches long. Mr. J. G. Munro, manager of the Molokai Ranch, stated that to his personal knowledge the cane had been there for twenty years, and a Hawaiian of Kaunakakai, a man well over sixty years of age, remembered having seen it in his childhood. It is probably safe to say that this cane has been growing in those rock pockets, with no care

Native cane in Kamakaipo Valley, Molokai.

whatever, and with an average rainfall of about twenty inches, for at least forty years. It has been protected from cattle and deer by the great boulders. Two such rock pockets were found, about two hundred yards apart, and Mr. Munro said he knew of two or three others, a mile or more distant. In the very few notes on Hawaiian canes that we have found in the literature, the consensus of opinion seems to be that these varieties are all poor ratooners, but the evidence offered by these stools would seem to disprove this contention.

On a trip into Halawa Valley, on the east end of the island, the first cane seen was Striped Tip, and the second was Yellow Tip. The Hawaiian owner of the taro patch, on the banks of which the canes were growing, called the striped one Pakaweli, which is probably incorrect. He had no name for the yellow cane, but stated very distinctly that they were not haole canes. On the return trip, a cane similar to White Bamboo, under the name Opukea, was found behind a Hawaiian house at Waialua.

At Kaunakakai a number of native canes were found which were making a beautiful growth. Among them was Ko Palani, said to have been at one time the best known of Hawaiian canes. This was the first time we had seen the cane, after hunting for it over most of Maui, Oahu and Molokai, and parts of Hawaii.

An attempt was made, by sampan, to visit Pelekunu, Wailau and Papalaua valleys, in which the natives claimed there was considerable cane, but the roughness of the sea made it impossible to land.

The plantation or haole canes found in Hawaiian gardens on Molokai were Lahaina, Kenikeni, Cavengerie, Rose Bamboo, and Striped Mexican.

A crossing from Pukoo to Lahaina was made by sampan, and a day spent in visiting the native cane and bud-selection plantings at Hamakuapoko and Waikapu. At the latter place it was discovered that the Lahaina fields, of which the plantation is very proud, contained very little Lahaina cane, at least in the parts inspected, the majority of the stools being the native cane Opukea. This is especially true of the large stools which were being groomed for the next fair. Mr. Burns, the assistant manager, remarked that Mr. Penhallow had always said that Wailuku's Lahaina was different from, and apparently better than, Puunene's. It seems as though this might be explained by a closer inspection of the two plantations, which would possibly show that Puunene's Lahaina was Lahaina, while Wailuku's was mainly Opukea.

Fiji Disease.

By H. L. Lyon.

The one critical symptom by which Fiji disease may be recognized is the occurrence of elongated swellings or galls on the under surface of the leaves. These galls extend along the larger veins or vascular bundles and are, in fact,

formed by the abnormal growth of the tissues comprising these bundles (Figs. 1 and 2).

Galls are produced in similar manner in the vascular bundles of the stem and may be detected by splitting open the stick of an affected shoot.

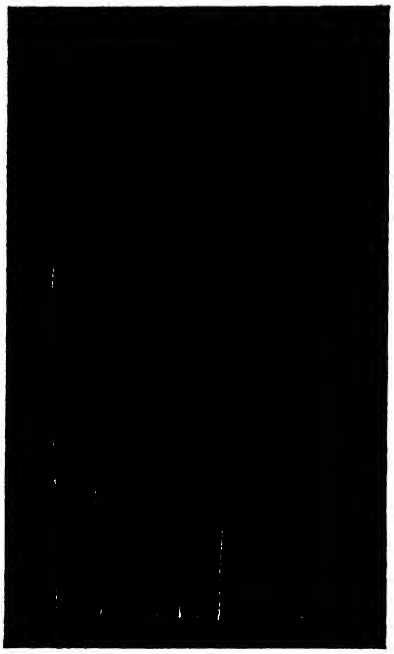


Fig. 1. *Fiji Disease.* Portion of a cane leaf seen from below, showing the ridge-like galls along the veins.

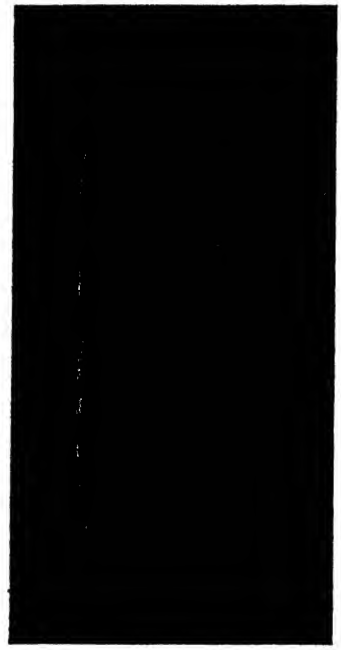


Fig. 2. *Fiji Disease.* Two leaf galls enlarged twelve diameters.

Galls of this nature are not induced by any other known cane disease and consequently their presence on the leaves or in the stem of a cane plant may be accepted as conclusive evidence that that plant is afflicted with Fiji disease.

The most conspicuous symptom of Fiji disease to be noted in the field is a shortening and crumpling of the last leaves to unfold from the spindle (Figs. 3 and 4). This peculiarity will attract the attention when one is still a considerable distance from the affected cane. A diseased shoot may attain considerable length and be clothed with many healthy looking leaves of the usual length and color, but of a sudden it loses the power to produce normal leaves, throws out a few bent and twisted stumps and then ceases to grow altogether. Some of the eyes may start, but the resulting lalas soon repeat the antics of the main stem. The stick may remain alive for months or it may soon die.

When such a stick is examined the characteristic galls are usually to be found on most of the healthy-looking leaves which are not otherwise distorted and on all of the deformed, aborted leaves. These latter leaves look as though they had been burned or scalded before expanding, the injury destroying the upper half or two-thirds of the leaf blades, leaving short crumpled stumps (Figs. 4 and 5).

Fig. 3. *Fiji Disease*. A stool of Badila cane in the last throes of the disease. Photo by Mr. North.

As indicated above, this abortion and distortion of the young leaves marks the culmination of the disease in a shoot and the last efforts of the growing point to throw out leaves. A shoot may throw out leaf after leaf bearing galls, but otherwise normal, and grow on for months as though perfectly healthy; then of a sudden comes this final spasm in its growth, and it is done. The appearance of galls on the leaves is the first outward symptom by which the disease may be detected, but a cane may be hopelessly infected with it for months before any galls appear. The disease is therefore cumulative in the cane; the galls mark a well advanced stage of the disease, and the distortion of the apical leaves its final culmination.

No variety of cane has yet been found which is immune to Fiji disease. Some varieties will grow eighteen months or more after infection before any galls appear. On other varieties, however, the galls appear soon after infection and the final spasm quickly follows. Thus it is that some of the more susceptible varieties are unable to make any growth at all on soil containing the germs

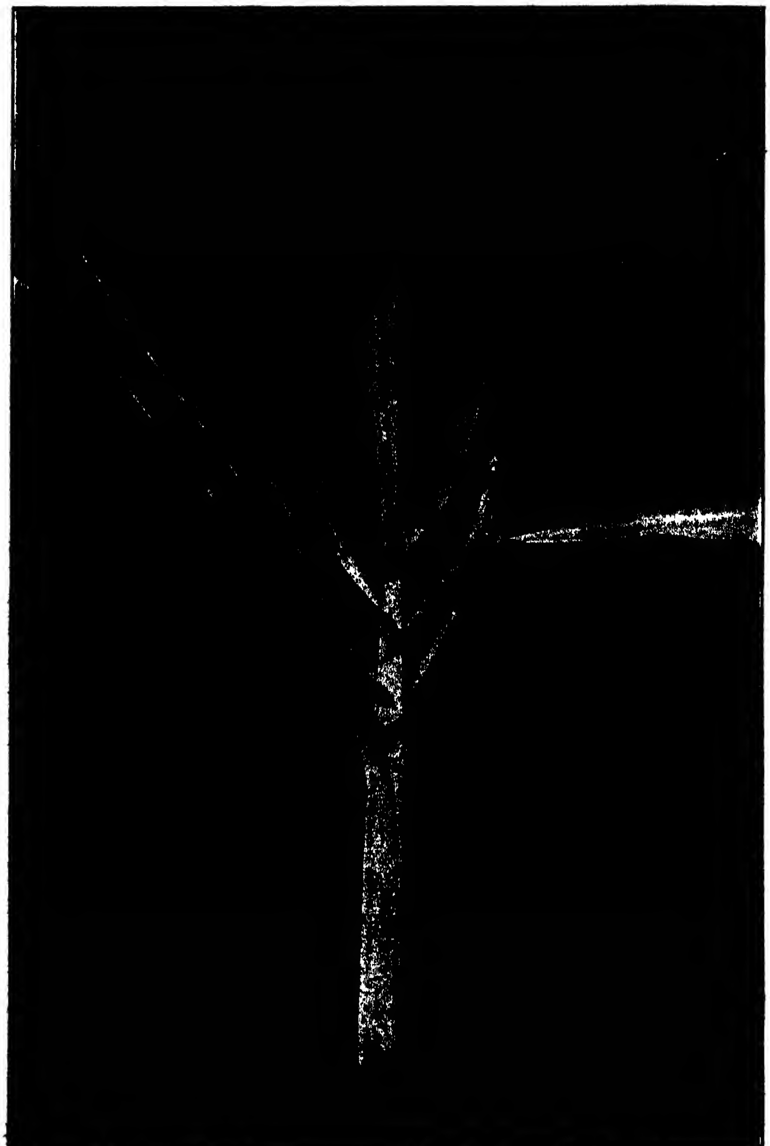


Fig. 4. *Fiji Disease.* This stalk has made its final effort to throw out leaves. Photo by Mr. North.

of the disease. Lahaina, H 109, and D 1135 have proven very susceptible to the malady.

The very existence of the sugar industry of Fiji was at one time gravely threatened by this disease. At the present time the industry is thriving, with the disease quite under control. The planters of Fiji hold that this has been accom-

plished by employing resistant varieties and by selecting only healthy canes for seed; but their system of rotation has undoubtedly been a most important factor in effecting this control. Their general practice is to take but one ratoon crop and then to keep the land under beans for a year before again planting it to cane. Early in their experience with the malady they discovered that it rarely

Fig. 5. *Fiji Disease.* Distorted leaves from the tops of canes which had been overcome by the disease. Photo by Mr. North.

attacks cane growing on poor soil and consequently they find it expedient to take their seed from their poorest fields. In this way they obtain cuttings comparatively free from infection and the resulting stools are able to grow two years or more on the heaviest soils before the disease overtakes and destroys them.

In a recent letter Mr. D. S. North of the Colonial Sugar Refining Company states that Badila is still the standard variety in Fiji and that, up to the present time, they have not succeeded in finding a variety more resistant to Fiji disease.

During his recent sojourn in Fiji, Mr. Pemberton wrote on Fiji disease as follows:

"As mentioned in a former letter, the Fiji disease is now completely under control in Fiji. I have discussed the plan of operation against this disease with many of the C. S. R. people and the independent planters. Their method has been universally the same and the results have been entirely successful everywhere. Should Fiji disease ever reach Hawaii, their successful experience in checking and almost eradicating it will be of great value to Hawaii through the adoption of the same methods. The results have been achieved entirely through seed selection.

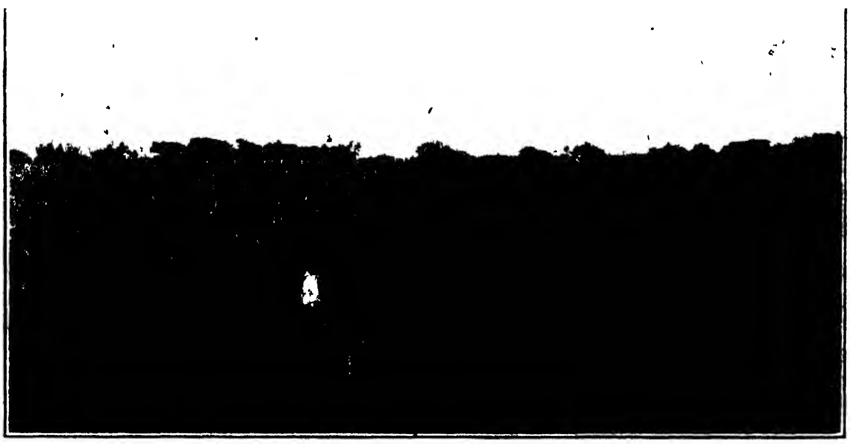


Fig. 6. *Fiji Disease.* First ratoons at Nadi. The variety on the left is Childers Zigzag, a cane that has proven very resistant to the disease, while the variety on the right is Daniel Dupont, a cane that is very susceptible to the disease, but not easily killed out by it. Every stool of the Dupont was alive, but consisted of short leaves only, there being no sticks at all.

"The selection of seed for planting, free from outward evidences of Fiji disease, goes on as rigorously now as ever, though it is usually difficult to find stools affected by it. Specially experienced men pass along the rows and cut seed only from *stools* which show absolutely no signs of the disease. It is a matter of stool selection, rather than a selection of good sticks. Sometimes a vigorous stool will show one stick affected. The entire stool is left standing and goes to the mill to be ground, or, as on some estates, it is dug up and burned. This simple selection of seed from only healthy stools seems to have resulted in a complete control of the disease. I have been told by some of the independent planters that a brief laxity in such selection for a few seasons results in a quick ascendant return of the disease in all of the newly-planted fields.

"Mauritius bean, as a green manure, is as enthusiastically cultivated as ever, excepting at Nausori. The system of rotation described by Dr. Lyon in the June, 1911, issue of the *Planters' Record* is still scrupulously adhered to by all independent planters leasing land from the C. S. R. Company and on all C. S. R. cane land."

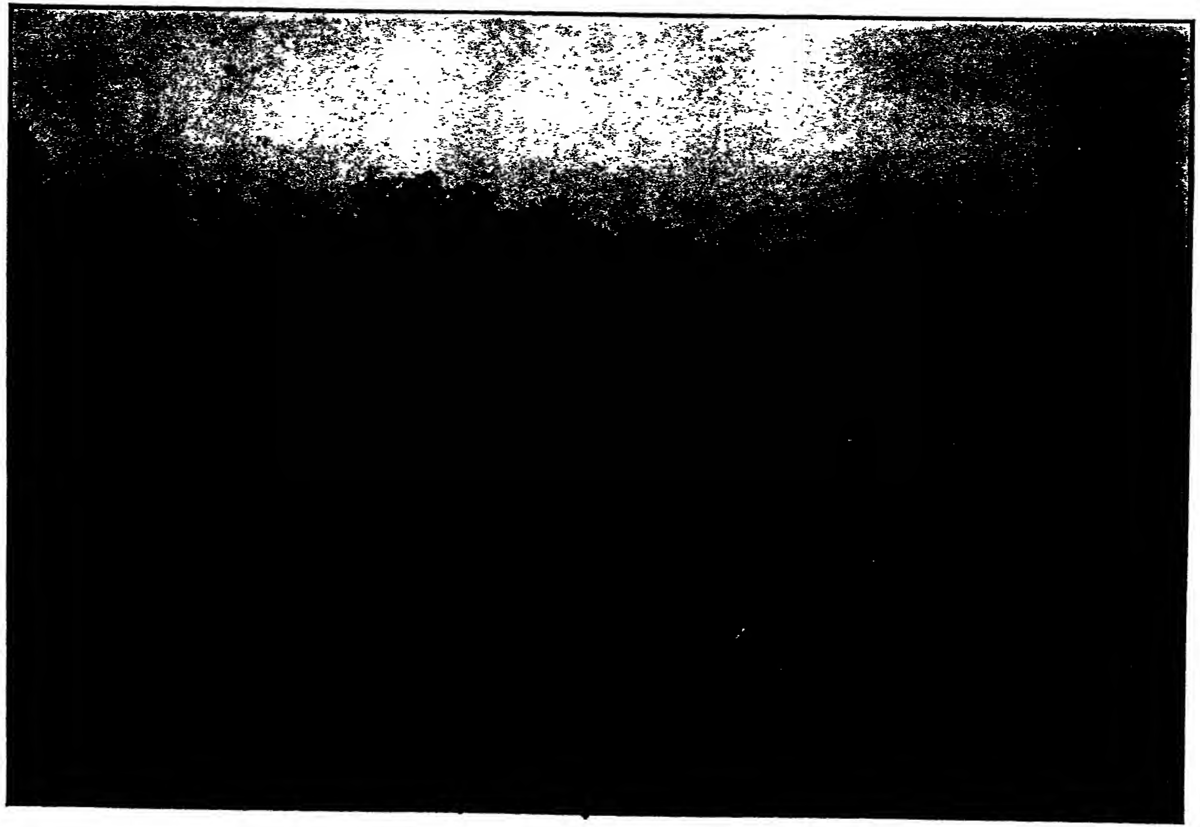


Fig. 7. *Fiji Disease.* Seventeen months plant cane affected with the disease. Of variety in foreground, every stool is dead. Of variety in background to left, 80% of stools are attacked, but too recently to be greatly damaged.

If Fiji disease ever appears on cane in Hawaii we shall no doubt detect it before it has spread to any extent, and take measures to completely eradicate it. Its general occurrence in Hawaii would undoubtedly compel us to abandon the culture of some of our favorite varieties such as Lahaina, H 109, and D 1135, and at the same time force us to replant our fields after taking one ratoon.

Phosphoric Acid Experiments at Hakalau.

The object of these experiments was to study the residual effects of phosphoric acid fertilization under conditions existing along the Hilo coast. These experiments involved the questions:

1. Does the application of phosphoric acid in addition to nitrogen increase yields?
2. If so, how much should be applied?
3. If so, what is the best form to apply?
4. If so, is raw rock phosphate in one large dose, enough to last four crops, more profitable than an equal money value of phosphoric acid as reverted phosphate applied one-fourth to each of four crops?

This series of experiments was harvested in 1919[1] as plant cane. For that crop the results were negative. That is, the omission of phosphoric acid did not in any way cause a reduction in yields, or conversely, the addition of phosphoric acid did not increase either the yield of cane or sugar. It was considered essential, however, that these experiments be repeated to note the residual effect of these phosphoric acid applications.

Now, again, the combined results of these experiments give a negative response. Cane which has received nitrogen but no phosphoric acid for four years has produced as large crops as has that receiving both nitrogen and phosphoric acid. Varying the amount of phosphoric acid from 100 pounds per acre to 400 pounds per acre caused no increase in yield, while applying phosphoric acid in various forms has produced no effect. The money expended in the purchase and application of phosphoric acid, under these conditions, has not been returned by any increase of yield during the plant and first ratoon crop.

HAKALAU EXPERIMENT NO. 4, 1921 CROP.*

SUMMARY.

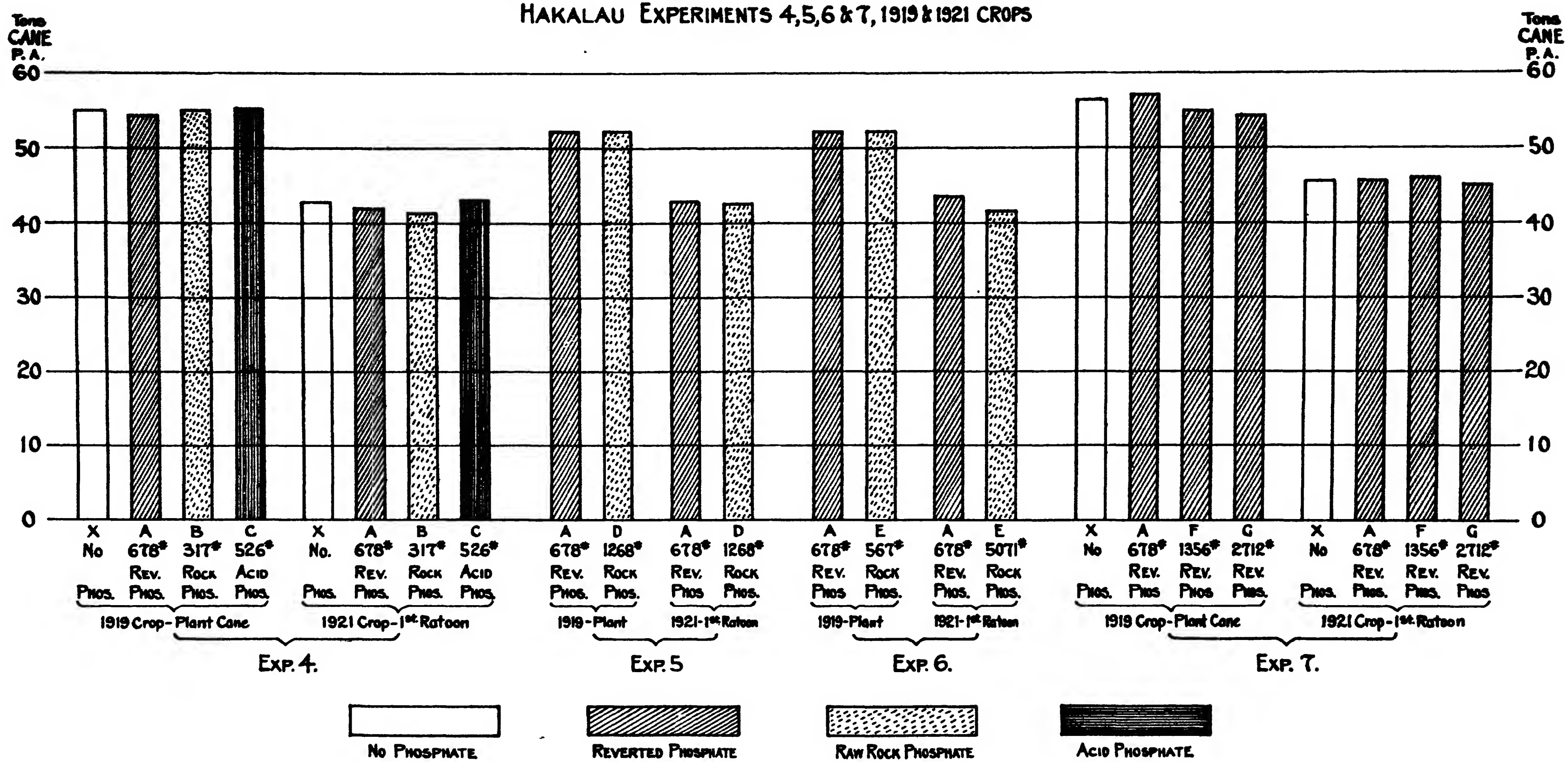
This was a comparison of 100 pounds of phosphoric acid applied as:

A. Reverted phosphate;
B. Raw rock phosphate;
C. Acid phosphate;
X. No phosphate.

[1] Reported in Record, Vol. XXI, p. 72.

* Experiment originally planned by L. D. Larsen.
Experiment laid out by W. P. Alexander and J. S. B. Pratt, Jr.
Experiment harvested by W. L. S. Williams.

KINDS AND AMOUNTS OF PHOSPHORIC ACID.
HAKALAU EXPERIMENTS 4, 5, 6 & 7, 1919 & 1921 CROPS



KINDS AND AMOUNTS OF PHOSPHORIC ACID

HAKALAU EXPERIMENTS 4, 5, 6 & 7, 1919 & 1921 CROPS

Plan Showing The Relative Positions Of The Experiments And Plots, One To Another And Plot Yields For 1921 Crop

Plots	Exp. 7		Exp. 6.	Exp. 5.	Exp. 4.	
1	X 55.99	F 43.99	E 45.77	A 39.51	X 45.11	A 45.09
2	A 60.75	G 41.78	A 43.52	D 35.32	C 47.95	X 46.74
3	F 60.57	X 39.88	E 44.16	A 43.46	X 39.45	B 44.58
4	G 58.86	A 41.43	A 43.60	D 41.92	A 39.89	X 46.93
5	X 52.96	F 47.86	E 43.08	A 45.47	X 40.37	C 40.13
6	A 41.94	G 36.59	A 39.91	D 45.56	B 45.50	X 46.29
7	F 43.25	X 40.81	E 38.25	A 41.70	X 43.82	A 39.95
8	G 50.73	A 40.98	A 41.23	D 39.48	C 45.92	X 39.49
9	X 50.57	F 36.71	E 37.44	A 37.15	X 38.58	B 37.73
10	A 55.40	G 44.40	A 42.97	D 41.35	A 40.12	X 35.73
11	F 52.93	X 39.98	E 38.74	A 39.60	X 42.82	C 38.16
12	G 49.86	A 36.86	A 38.80	D 38.36	B 38.83	X 43.96
13	X 46.09	F 40.52	E 38.17	A 42.92	X 40.50	A 43.15
14	A 44.08	G 40.21	A 43.22	D 44.29	C 44.26	X 40.76
15	F 39.00	X 43.97	E 37.35	A 47.71	X 48.96	B 41.97
16	G 36.39	A 44.87	A 46.72	D 46.18	A 45.38	X 43.62
17	X 40.00	F 50.11	E 50.59	A 47.97	X 45.81	C 44.25
18	A 45.89	G 42.75	A 46.38	D 42.34	B 36.54	X 43.53
19	F 49.32	X 46.91	E 43.66	A 42.87	X 42.75	A 44.51
20	G 51.24	A 45.59	A 45.32	D 44.37	C 42.05	X 39.10
21	X 48.37	F 46.60	E 41.85	A 41.73	X 41.11	B 41.61
22	A 48.68	G 44.67	A 47.71	D 46.00	A 39.86	X 48.41
23	F 44.97	X 44.02	E 42.99	A 46.83	X 45.27	C 43.97
24	G 46.23	A 45.99	A 45.23	D 48.14	B 45.22	X 40.13

Summary of Results (Exp. 7.)

Plots	Treatment	Cane Yields - Tons Per Acre.	
		1919-Plant Cane	1921-1st Ratoon
X	No Phosphate	56.65	45.79
A	678# Rev. Phos.	57.32	46.04
F	1356# Rev. Phos.	55.19	46.32
G	2712# Rev. Phos.	54.49	45.31

Summary of Results (Exp. 6.)

Plots	Treatment	Cane Yields - Tons Per Acre	
		1919-Plant Cane	1921-1st Ratoon
A	678# Rev. Phos.	52.43	43.72
E	5071# Rock Phos.	52.54	41.84

Summary of Results (Exp. 5.)

Plots	Treatment	Cane Yields - Tons Per Acre	
		1919-Plant Cane	1921-1st Ratoon
A	678# Rev. Phos.	52.37	43.08
D	1266# Rock Phos.	52.37	42.78

Summary of Results (Exp. 4.)

Plots	Treatment	Cane Yields - Tons Per Acre	
		1919-Plant Cane	1921-1st Ratoon
X	No Phosphate	55.20	42.89
A	678# Rev. Phos.	54.50	42.24
B	317# Rock Phos.	55.20	41.50
C	526# Acid Phos.	55.40	43.33

The phosphates were applied in the furrow before planting. For the present crop all plots received a uniform dose of 1200 pounds nitrate of soda applied in four equal doses. The following tabulation shows the treatment and yield in cane for this crop and the total yield in cane for the past two crops, plant and first ratoon:

Plot	Treatment	Yields—Tons per Acre	
		First Ratoon	Plant and First Ratoon
A	Reverted phosphate ..	42.24	96.74
B	Raw rock phosphate ..	41.50	96.70
C	Acid phosphate	43.33	98.73
X	No phosphate	42.88	98.08

The average yield for the two crops of the three kinds of phosphate is 97.39 tons cane, while that for no phosphate is 98.08 tons cane per acre. This shows that cane in this district does not respond to phosphoric acid.

DETAILS OF EXPERIMENT.

Object:

1. To test the residual fertilizing value of phosphoric acid in various forms.
2. To compare equal amounts of phosphoric acid applied as:
   - A. Reverted phosphate,
   - B. Raw rock phosphate,
   - C. Acid phosphate.

Location:

Field 10.

Crop:

Yellow Caledonia, plant cane.

Layout:

No. of plots: 48.
Size of plots: 1/10 acre each, consisting of 6 lines, each line 5.65 feet wide and 128.3 feet long.

Plan:

Plot	No. Plots	Phosphate—Pounds per Acre*	Pounds P_2O_5 per Acre
A	8	678 reverted phosphate (14.73%).....	100
B	8	317 raw rock phosphate (31.55%).....	100
C	8	526 acid phosphate (19%)...........	100
X	24	0	

* Applied in furrow to previous crop before planting.

Fertilization:

	Pounds Nitrate of Soda per Acre				Total Pounds Nitrogen
	Aug., 1919	Oct., 1919	Jan., 1920	Apr., 1920	
All Plots ...	300	300	300	300	186

PROGRESS OF EXPERIMENT.

June 25, 1919—Experiment off-barred.
August 19, 1919—Fertilized, 300 pounds N. S. per acre.
October 6, 1919—Fertilized, 300 pounds N. S. per acre.
January 16, 1920—Fertilized, 300 pounds N. S. per acre.
April 13, 1920—Fertilized, 300 pounds N. S. per acre.
January 25-February 7, 1921—Experiment harvested by W. L. S. Williams.

HAKALAU EXPERIMENTS 5 AND 6,** 1921 CROP.

These two experiments dealing with reverted and raw rock phosphate are so closely related that they are summarized together.

In Experiment No. 5, comparison is made between the residual values of phosphoric acid applied in equal money values as reverted and raw rock phosphate. The phosphates were applied in the furrow to the previous crop before planting. The fertilization of the present crop was uniform to all plots, consisting of 1200 pounds nitrate of soda applied in four equal doses. The following tabulation shows the yields of cane for this crop and the total yield of cane for the two crops, plant and first ratoon:

Plot	Treatment	Yields in Tons Cane per Acre	
		First Ratoon	Plant and First Ratoon
A	678 lbs. reverted phosphate...	43.08	95.45
D	1268 lbs. raw rock phosphate...	42.78	95.15

In Experiment 6, comparison is made between the residual effect of phosphoric acid applied in one large dose as raw rock phosphate to last four crops, with an equal money value of phosphoric acid as reverted phosphate, one-fourth applied with each of four crops. The raw rock phosphate was applied in the furrow before planting, while one-fourth the reverted phosphate was applied to the plant crop and one-fourth to the present crop. Fertilization to this crop was uniform to all plots, consisting of 1200 pounds nitrate of soda applied in four equal doses. The following tabulation shows the yields of cane for this crop and the total yield of cane for the two crops, plant and first ratoon:

** Experiment originally planned by L. D. Larsen.
Experiment laid out by W. P. Alexander and J. S. B. Pratt, Jr.

Plot	Treatment	Pounds P_2O_5 per Acre	Cane Yields—Tons per Acre	
			First Ratoon	Plant and First Ratoon
A	678 lbs. reverted phosphate..	100	43.72	96.15
E	5071 lbs. raw rock phosphate..	1600	41.84	94.38

NOTE:—The A plots have to date received 200 pounds phosphoric acid, half to each crop.

DETAILED ACCOUNT, EXPERIMENT 5.

Object:

To compare residual effect of equal money values of reverted and raw rock phosphate.

Location:

Field 10.

Layout:

No. of plots: 24.

Size of plots: 1/10 acre each, consisting of 6 lines, each 5.65 feet wide and 128.3 feet long.

Crop:

Yellow Caledonia, first ratoons, long.

Plan:

Plot	No. Plots	Pounds Phosphate per Acre*	Pounds P_2O_5 per Acre
A	12	678 lbs. reverted phosphate (14.73%)..	100
D	12	1268 lbs. raw rock phosphate (31.55%)..	400

* Applied in furrow before planting.

Fertilization uniform to all plots, as follows:

	Pounds Nitrate of Soda per Acre				Total Pounds Nitrogen
	Aug., 1919	Oct., 1919	Jan., 1920	Apr., 1920	
All Plots ...	300	300	300	300	186

PROGRESS OF EXPERIMENT 5.

May, 1919—Previous crop harvested.
June 25, 1919—Experiment off-barred.
August 19, 1919—First fertilization, 300 pounds N. S. per acre.
October 7, 1919—Second fertilization, 300 pounds N. S. per acre.
January 16, 1920—Third fertilization, 300 pounds N. S. per acre.
April 13, 1920—Fourth fertilization, 300 pounds N. S. per acre.
January 25-February 3, 1921—Experiment harvested by W. L. S. Williams.

DETAILED ACCOUNT, EXPERIMENT 6.

Object:

To compare the value of phosphoric acid applied in one large dose as raw rock phosphate, to last four crops, with an equal money value of phosphoric acid as reverted phosphate, one-fourth to each of four crops.

Location:

Field 10.

Layout:

No. of plots: 24.
Size of plots: 1/10 acre each, consisting of 6 lines, each 5.65 feet wide and 128.3 feet long.

Crop:

Yellow Caledonia, first ratoons.

Plan:

Plot	No. Plots	Pounds Phosphate per Acre	Pounds P_2O_5 per Acre
A	12	678 lbs. reverted phosphate (14.72%)..	100
E	12	5071 lbs. raw rock phosphate (31.55%)..	1600

NOTE:—Reverted phosphate applied to each crop; raw rock applied to plant cane in furrow before planting.

Fertilization:

	Pounds Nitrate of Soda per Acre				Total Pounds Nitrogen per Acre
	Aug., 1919	Oct., 1919	Jan., 1920	Apr., 1920	
All Plots ..	300	300	300	300	186

PROGRESS OF EXPERIMENT.

May, 1919—Previous crop harvested.
June 25, 1919—Experiment off-barred.
August 20, 1919—First fertilization, 300 pounds N. S. per acre.
August 25, 1919—A plots received 678 pounds reverted phosphate per acre.
October 6, 1919—Second fertilization, 300 pounds N. S. per acre.
January 17, 1920—Third fertilization, 300 pounds N. S. per acre.
April 14, 1920—Fourth fertilization, 300 pounds N. S. per acre.
January 25-February 3, 1921—Experiment harvested by W. L. S. Williams.

HAKALAU EXPERIMENT 7, 1921 CROP.*

SUMMARY.

This experiment is one testing the residual effect of phosphoric acid applied at the rate of 0, 100 pounds, 200 pounds, and 400 pounds per acre as reverted phosphate. The phosphate was applied in the furrow before planting. Fertili-

* Experiment originally planned by L. D. Larsen.
Experiment laid out by W. P. Alexander and J. S. B. Pratt, Jr.

zation of the present crop has been uniform to all plots, consisting of 1200 pounds of nitrate of soda in four equal doses. The following tabulation shows the cane yields for this crop and the combined yields for the 1919 and 1921 crops:

Plot	Treatment in Pounds Reverted Phosphate per Acre	Cane Yields in Tons per Acre	
		First Ratoon	Plant and First Ratoon
A	678	46.04	103.36
F	1356	46.32	101.51
G	2712	45.31	99.80
X	0	45.79	102.44

The conclusions to be drawn from this experiment are that the cost of the phosphate and its application has not been compensated for by any increase in yield.

DETAILS OF EXPERIMENT.

Object:

To compare 0, 100, 200, and 400 pounds phosphoric acid.

Location:

Field 10.

Crop:

Yellow Caledonia, first ratoons, long.

Layout:

No. of plots: 48.
Size of plots: 1/10 acre each, consisting of 6 lines, each 5.65 feet wide and 128.3 feet long.

Plan:

Plot	No. Plots	Pounds Reverted Phosphate per Acre*	Pounds P_2O_5 per Acre
A	12	678	100
F	12	1356	200
G	12	2712	400
X	12	0	0

* Applied in furrow before planting.

Fertilization:

	Pounds Nitrate of Soda per Acre				Total Pounds Nitrate Soda per Acre
	Aug., 1919	Oct., 1919	Jan., 1920	Apr., 1920	
All Plots ...	300	300	300	300	186

PROGRESS OF EXPERIMENT.

May, 1919—Last crop harvested.
June 25, 1919—Experiment off-barred.
August 20, 1919—First fertilization, 300 pounds N. S. per acre.
October 6, 1919—Second fertilization, 300 pounds N. S. per acre.
January 17, 1920—Third fertilization, 300 pounds N. S. per acre.
April 14, 1920—Fourth fertilization, 300 pounds N. S. per acre.
January 25-February 2, 1921—Experiment harvested by W. L. S. Williams.

R. S. T.

The Economical Use of Irrigation Water.*

By Guy R. Stewart.

A considerable number of our Hawaiian plantations depend entirely upon irrigation water to raise any sort of successful cane crops. An equally large group rely principally upon the annual rainfall. Some of the lower fields may be irrigated on the latter plantations, but the principal use made of ditch water in ordinary years is to flume the cane down to the mill. Extraordinary years, with light rainfall, come everywhere, even in the Hawaiian Islands. The past dry years have shown there is no such thing as dependable rains. Many a plantation has figured this last year on the extra use that might be made of the flume water after it left the loading stations or the mill. There are a few places, which have never irrigated before, that are now planning to contour their lower fields when they replant them, so the crop could be carried through another dry spell. Such a year as the past one has made everyone unusually interested in getting everything that is possible out of all the water on the plantation.

The economical use of water not only consists of getting it onto the fields that are suffering in a dry spell, but also in making the most of the regular supply on the irrigated plantations. The same simple principles apply in either case. The first thing to be considered in the economical operation of any ditch system is, how large is the transmission loss. That is to say, what per cent of the water that leaves the pump head, or the ditch intake, finally gets into the watercourses in the cane fields. Every plantation ought to know just how much water disappears along the way.

The only sure method of checking up on this loss is by accurately measuring the water where it enters the system, then measuring it again into the main distributing ditches, and finally into the field laterals. If the per cent of loss from seepage is at all high, the main ditches and laterals can be given a concrete surface. This seepage loss will depend largely upon the nature of the soil and subsoil, and also on the length of time the ditch has been in operation. In soils that are inclined to silt, or puddle, the loss will decrease as the ditches are used. If the water has to be transported many miles, it has generally been found that the loss is sufficient to pay for surfacing the ditches.

* A lecture delivered at the Short Course for Plantation Men, University of Hawaii, October, 1920.

Water Measurement.

There are several systems of units used for expressing the flow of a stream, or the head of water developed by a pump. These units are easily changed from one system to another, as indicated in the following brief table of the more important values:

Table of Water Measurement.

1 cubic foot = 7.5 gallons (7.48 exact).
1 acre foot = 43,560 acre feet = 323,136 gallons.
1 second foot = 7.5 gallons per second = 450 gallons per minute.
1 second foot in 24 hours gives nearly 2 acre feet (1.983 exact).
1 second foot in 1 hour gives nearly one acre inch.
1 second foot is equivalent to 40 miner's inches (controlled by a 6-inch pressure head).

If we know the daily discharge of a pump in gallons, we can readily change the figure to acre feet by dividing by 323,136, or to second feet by dividing the flow per minute by 450.

It will be seen in the above table that there are really four methods of water measurement. These are: to state the amount in gallons; in cubic feet per second; in acre feet; or in miner's inches. The expression in acre inches or acre feet is generally used for the amount of water applied to land, as it immediately indicates how heavy the irrigation will be when spread over the field. Stream flow is usually given in terms of cubic feet per second.

The entire question of stream measurement is too extensive to be dealt with here in great detail. The theory underlying the operations is extremely simple, but various precautions must be observed in order to obtain accurate results. If we have a flume 12 inches wide carrying water to the depth of 12 inches, placed on such a grade that the water flows at the rate of 1 lineal foot per second, this will give a flow of 1 cubic foot per second. That is to say, the cross-section of a flume or ditch, multiplied by the velocity in feet per second, gives the flow in cubic feet per second.

In open streams it is necessary to have a gauging station where the vertical area across the stream is measured and the velocity of the current determined by a current meter or float. The most usual method of measuring the flow of a ditch is by one of the standard weirs, which are essentially boxes through which the water flows with a constant head. Tables are made up for various forms of weirs which you can find in engineering handbooks or reference books on irrigation.

Soil Moisture.

Let us now suppose that the ditch water has been delivered to the field with the smallest possible loss. Probably most field men have observed that the seepage loss from the field laterals is reduced by using as large a stream as the men can conveniently handle. There is no surer way to lose water than to divide up the irrigation head so that each man works separately with a small stream in a different part of the field.

We now have the water applied to the actual soil, and it will be well to refer

again to some of the things you have already heard about soil moisture. Water may exist in the soil in three different ways. First, all soil contains hygroscopic moisture. This is the moisture that stays in the soil even when it appears to be dry as dust. It is ordinarily determined by exposing a thin layer of soil to air that is saturated with moisture. In this way we find the greatest possible hygroscopic capacity of the soil. The most important type of moisture for plants is the second form, which we call capillary moisture. This water is the thin film which is held around the soil particles.

If we place a small glass tube of about ⅛-inch bore in a tumbler of water, we find the water will rise a fraction of an inch in height above the surface of the tumbler. If the tube is of extremely small bore, about as large as a coarse hair, the water will rise several inches in height. This same force of capillarity carries water in soils from one particle to another either up or down. Just as with the tube, the smaller the openings are, the higher the water will rise. In a coarse sand, water rises quickly for a short distance, while in a fine silt loam it will ascend a number of feet, but will require several days to do this.

As more water is applied to soil, the capillary moisture increases till we reach the maximum moisture-holding capacity. We then have free water flowing through the soil. If this continues, and the drainage capacity is not equal to the amount put on, we drive the air out of the soil and it becomes waterlogged. It has been found that the optimum moisture content for most soils is forty to sixty per cent of the maximum water-holding capacity. We should never add sufficient moisture to bring the water in the whole soil mass greatly above the optimum for any length of time.

Verret and Allen found that one inch of rain or irrigation would wet the soil at the Waipio Substation down to a depth of 10 to 12 inches. The soil there will retain all except 3% of a 2-inch irrigation, 47% of a 6-inch irrigation, and 65% of a 9-inch irrigation. This shows the great loss of water there is from one irrigation on a typical silty clay soil.

A number of interesting experiments have been made at various places in the United States to try and discover what part of the water held in the soil can be used by the plant. These studies were made by growing small plants in pots sealed over with soft wax to prevent surface evaporation. The plants were allowed to grow until they wilted. They were then put in a chamber with moist air to see if they would revive. If the plants remained wilted, this was called the wilting point, and the per cent of moisture remaining in the soil was called the wilting coefficient of that soil. In general, it has been found that the hygroscopic moisture is slightly lower than the wilting coefficient.

Some of the relationships of the various physical constants are shown in the following table. The figures given are the average of a number of determinations, and in the case of the mainland soils it shows the increase in moisture-holding capacity that is caused by finer texture and larger amounts of clay. A large part of our Hawaiian soils would be classed as clays or silty clay loams, and possess a remarkable capacity for holding water. Organic matter also increases a soil's power to hold moisture, and many Island soils owe part of their moisture-holding capacity to a high content of decomposed vegetable matter.

RELATION OF PHYSICAL CONSTANTS OF SOILS.

	Hygroscopic Coefficient	Wilting Coefficient	Optimum Moisture	Maximum Moisture-Holding Capacity
Mainland Soils:				
Coarse sand	0.5	0.9	13.8	23.2
Fine sand	1.5	2.6	17.9	29.9
Sandy loam	3.5	4.8	26.9	44.9
Loam	9.8	13.9	33.3	55.9
Clay loam	11.8	14.6	32.5	54.2
Hawaiian Soils:				
Onomea Plantation	21.4	...	49.2	82.2
Pepeekeo Plantation	21.6	...	53.9	89.9
Hamakua Plantation	22.3	...	60.0	100.2
Honokaa Plantation	22.6	...	53.0	89.1
Hawi Mill	17.1	...	36.0	60.0
Hawaiian Sugar Co.	16.8	...	34.0	57.7
Lihue and Grove Farm	19.7	...	36.6	61.5
Kilauea	19.4	...	36.0	60.0

Field Applications.

We see that the useful moisture for the plant lies between the wilting point of the soil and the optimum moisture capacity. If we greatly exceed the optimum we destroy the soil's aeration and also waste a large amount of irrigation water. It has been found that practically all plants grow best if the soil is kept reasonably close to its optimum content of moisture during the early part of the plant's growth. Most grain crops ripen best if the moisture is reduced in the soil for a few weeks before harvesting, thus forcing the plant to complete maturity. This has also been found to be the case with sugar cane.

In field work, then, our greatest economy will be obtained in the use of irrigation water, if we irrigate frequently enough to keep the soil close to the optimum when the cane is making its heaviest growth. We must avoid adding water in such quantity that there will be a large underground run-off and the lower soil possibly waterlogged. Evidently the different soils on the same plantation will be found to vary considerably in their water requirements. Here is where soil augers in the hands of the field men will be found of great value. Anyone who goes through a cane field can easily see whether the soil is dry enough for the cane to wilt, but it takes an actual boring down into the subsoil to see whether the soil is up to optimum moisture content or over it.

The optimum moisture content of a soil can soon be recognized simply by feeling the soil brought up by the auger. Everyone who has plowed land knows the point at which the soil works the best and turns a perfect furrow. This point of ideal working for plowing or spading is slightly below the optimum moisture content. Soil which forms a pasty mass when the borings are taken out of the auger is above the optimum content and not far from the point where free water can be pressed out. A little experience in the field with an auger

making borings to a depth of two to four feet will soon develop very definite knowledge about the fields of any plantation.

It is a good plan to make several borings before a field is irrigated and then check the moisture condition of the soil by boring at intervals of a few days until the field is irrigated again. In this way the men handling the irrigating gangs will soon learn how much water their fields actually require. They will frequently find some areas that dry out more rapidly than the balance of the field. The addition of mud press or stable manure, if the spots are not too large, will generally improve the water-holding capacity and allow them to irrigate the field only when the whole area requires water.

Report of Committee on Juice Deterioration.*

By W. R. McAllep.

Your Committee on Juice Deterioration has the following report to make:

Contributions on the subject of the deterioration of juice in the settling tanks when the juice is kept over night or over the week end have been received from Mr. V. P. Iyer, Mr. A. Fries, Mr. H. L. White, and Mr. H. S. Walker.

We will present Mr. Iyer's paper first.

"During the latter part of the season at Waiakea Mill Co., we worked during the day only. Conditions compelled us to leave all the juices in mixed juice measuring tanks, settling tanks, and the evaporator juice supply tanks, as soon as the mill stopped grinding in the evening, till next day. The curiosity to see if there were any, and if so, how much deterioration took place in leaving the juices and syrup at the end of the week during the time when there were two shifts, led us to make frequent tests which were done throughout the crop. The analyses of these are as follows, arranged according to the order in which they were performed. In order that the analyses may not be influenced by autosuggestion and preconceived conclusions, the corrected Brix, % polarization, and purity were calculated after the tests were made.

Mr. W. R. McAllep of the Experiment Station during his visit of inspection to the mill recommended that the juice in the juice heater be kept at a lower temperature for an hour before the mill stopped grinding for the day, according to the results of Mr. Walker's investigations at Pioneer Mill last year. This advice was followed throughout the balance of the crop during which tests No. 16 to No. 34 were performed."

The individual tests are omitted, but a summary by Mr. Iyer follows:

Test No.	Time Standing	Temperature, Initial – Final	Drop in Purity	Remarks
5	9½		1.65	No preservative.
8	10¼		1.42	No preservative.
16-18	9-12		1.80	No preservative.
19	11¼	198 – 162	0.71	No preservative.
20-23	11½	188 – 174	0.25	No preservative.
11	12½	Ordinary routine	2.34	No preservative.
29-34	13½	181 – 161	0.26	No preservative.
29-34	37½	126	2.46	No preservative.
24-28	24	182 – 145	1.00	No preservative.
24-28	37½	135	3.58	1.77 liters formalin added to each tank at end of 24 hours.
1	32¼	Ordinary routine	1.69	1.77 liters formalin per tank.

* Presented at the Eighteenth Annual Meeting of the Hawaiian Chemists' Association, held jointly with the Hawaiian Engineering Association, November, 1920.

"The number of tests does not warrant the expression of an opinion based on the above results. It seems that the juice stands fairly well for about 12 hours when the juice is passed through the heater at a lower temperature, but it is not safe to let the juice stand for a longer time than 24 hours, and we can safely state that the juice will not keep for 26 or more hours. There is a danger of some loss of sugar even in the case of thin syrup by letting it stand."

To these conclusions the writer would add that where the tanks were filled at a temperature below 190 and did not drop to a temperature below 160 the loss is much smaller than other cases. Mr. Iyer continues:

"Where the drippings of juice from the presses fall into the evaporator juice tank containing a considerable amount of good clarified and press juice at the end of the day, we may be certain that all that high-purity juice will deteriorate faster than when the drippings are not allowed to mix with it. Should the drippings be kept separate till next morning and then mixed up with the fresh evaporator juice and evaporated into syrup?

"The cold filter press juice from the first press, after the mill had stopped for 36 hours, was 40.6, and 39.7 purity on Monday morning as soon as the juice began to flow; if the purity is below 60, is it not better to throw that juice out altogether, as well as the cake left over in the presses? At Hamakua Mill Co., cake left in the presses over night sampled and immediately analyzed when the press cake was dumped out next morning gave an average polarization on five days of 6.4. What should be the lowest purity of the residual juice in the press cake left over night, below which the juice and the cake should be thrown out? This may not influence the final yield very much where the mill is grinding day and night, but will affect the yield in a place where only one shift prevails, especially if the dirty sour juice infects the whole boiling house and mill.

"The initial purity of the juice seems to exert an influence on the keeping quality of the juice, as seen in tests 20, 23, 24, 28, and 29-34. After 24 hours the lower purity juice deteriorated faster than a higher one. (See graph.) The following question suggests itself: What is the hourly variation in deterioration, say, up to 40 or even 48 or 72 hours? There may be some accidents in the mill which may compel the juice being kept that long without being boiled off. Under such conditions what should be the procedure or remedy to keep the juice from going back?

"Test No. 7, as well as tests Nos. 30, 32, and 34, show that when the juice is overlimed, it keeps well for a long time, but after 13½ hours it begins to drop in purity (tests Nos. 30, 32, and 34) greater than the juice showing acid reaction to litmus after 13½ hours (tests Nos. 29 and 31). This leads us to the following inquiry: Keeping the juice in the juice heater at low temperature, say around 180° F., should the juice be limed to neutrality, acidity, or alkalinity to litmus, in order to preserve for 12, 24, 36, and 48 hours, and if formalin should be added during the interval, and if so, how much? What difference will it make when the juice heater temperature is kept at 160, 170, 180, 190, and 200° F., keeping the liming and the time of the standing constant in each case? What will be the influence of keeping and not keeping the juice tanks well insulated and covered, and keeping the juice as nearly as possible at the temperature at which the tank is filled? What will be the influence of a drop in temperature of 10, 20, 30, 40, 50, and 60° F.? Also, what would be the change in procedure with juices of different purities ranging from 75 to 90 and with juices from different varieties of cane?

"Some members of the Association may have done much work along this line, and their experience and knowledge may help in throwing light on these problems."

Mr. Fries makes the following contribution:

"The 16 settling tanks at Makaweli are round, with conical bottoms, holding about 2000 gallons each, and are insulated, but not covered.

"During the past, crop tests were made at Makaweli as to the effect of temperature on the keeping qualities of the clarified juice. Mr. Walker claims two things from his experiments at Lahaina: (1) Loss of purity can be prevented by lowering the initial temperature to 180° F., and (2) formalin is of no value.

"In the tests made during May and June the juices were heated to 185° F., and the loss of purity after 20-25 hours was:

	Loss in Purity					Average.
With formalin	0.9	1.1	0.1	0.2	1.3	0.72
Without formalin	2.4	2.0	2.1	2.1	5.2	2.76

"During September—Juices heated to 185° showed after 12-15 hours:

	Loss in Purity					Average.
With formalin	0.7	0.3	0.1	0.0	0.1	0.24
Without formalin	0.5	0.2	0.1	0.2	0.2	0.24

	Time of Standing	
	15 Hours.	34 Hours.
Loss in purity with formalin	0.0	0.8
Loss in purity without formalin	0.2	2.6

"Comparisons of 212° and 185° temperature (no formalin used):

Temp.	Hrs.	Loss.	Hrs.	Loss.
212	13	0.02	19	0.45
185	13	0.22	19	0.52

These results differ radically from those at Lahaina; while the tests made in May and June indicate clearly that it pays to use formalin, even when heating to 185° F. The tests in September seemingly confirm Mr. Walker's experiments, if the time of remaining in the settling tanks does not exceed 15 hours, as for a considerably longer time of standing, the benefit of the formalin is unmistakable. It has further been brought out that the deterioration is not worse when heating to 212° than when lowering the temperature to 185°—that is, up to 19 hours.

"All this impels me to the belief that the differences between here and Lahaina and in the above tests indicate not so much a difference in apparatus or temperature, but in juices, and that by discontinuing the application of formalin, when juices have to remain in the settlers for any considerable time, the loss in sucrose involved in some factories may be a serious one, as it seems a well-established fact that at different factories the liquors are more sterile than in others. (This was found by the Experiment Station in connection with Chlorox experiments.)"

A tabulation of the deterioration of the clarified juice held over the week-end at Onomea has been contributed by Mr. White. Averages of the trials with and without formalin, and Mr. White's explanation, follow:

"The following table was compiled during the crop of 1920 and shows the inversion and losses taking place from the time the juice went into the settling tanks until it was taken to the evaporators. While no absolute record was kept of the temperature of the juice going in and coming out of the tanks, enough samples were taken to be approximately sure of the temperature. This was 89° C. (192° F.) going in and 68° C. (156° F.) coming out.

	Loss	
	Gravity Purity.	% Total Sucrose.
With formalin (15)	2.00	1.56
Without formalin (8)	2.40	1.78

"One test with formalin in which the juice stood for a longer period of time has been omitted from the averages."

Mr. Walker's contribution is as follows:

"Mr. Fries believes that the difference between his results and mine should be ascribed to a difference in the juice handled. While this may be possible, there is also the possibility that the uncovered tanks at Makaweli allow the juice to cool down below the critical point where certain bacteria can function. The open top would also tend to allow infection, even if the juice was previously sterile. Mr. Fries does not say what his final temperatures at the end of 15 or 24 hours were, and I am inclined to think most of the difference may lie there. As you remember, the experiment in which I found formalin 'worse than useless' was with an initial temperature of 212° and a final one of

196° F. On reducing initial temperatures to around 180°, deterioration in 24 hours was practically stopped, so formalin was unnecessary. It must be remembered, though, that on account of good insulation, none of my temperatures dropped below 170° in 24 hours. There certainly must be some temperature below this at which bacteria begin to get active and at which a preservative would be indicated. This point could easily be settled by keeping juice in a constant temperature oven at various temperatures. Along this line an interesting experiment would be to fill several flasks with hot juice from the settling tanks, plug with sterile cotton and let cool completely, polarizing, say, one flask every few hours to see what part heat-resisting organisms may play in juice deterioration.

"During the 1920 crop we ordinarily stopped grinding at 12 Saturday night and started up again between 6 and 8 Sunday night. Two or three 1100 cubic feet settling tanks were left full of hot juice each week from Saturday to Sunday, standing over on an average, 18 hours.

"Beginning January 17, purities were determined each week on at least one tank of juice before and after standing. Samples were taken about 2 a. m. Sunday morning and 9 Sunday night. The work was all done by our Japanese night chemist, who had no idea of its purpose, so the results could not have been influenced by any personal bias. Juice entering tanks was kept as near 180° F. as possible; on one or two occasions it went above 190°. Final temperatures were not taken, but former tests showed them to run uniformly a little above 170°.

"Following are the averages from 28 tests during 25 weeks grinding:

Average time of standing	18 hours
Average initial purity	86.37
Average final purity	86.16
Average loss	0.21

Greatest loss, January 17; juice stood 34 hours, dropped from 83.5 to 81.8. Least loss, June 26; juice stood 15 hours, rose from 79.7 to 81.6. No formalin was used this year."

The writer wished to present an extract from a report that has come into his possession on the bacterial flora of mills:

"The most difficult organism to guard against in the mill is a bacillus which for the present will be referred to as the 'High Temperature Organism.' It shows great variation in form and size, appearing as short rods, long rods, or even threads, which also vary in thickness. In this and other respects it closely resembles **Bac. Levaniformans**, and may, on further investigation, prove to be an abnormal race of that organism, which has acquired the power of growing at high temperatures, but has lost the property of forming gum. It has been found in every mill product from juice to molasses, and doubtless exists in all mills.

"It can be readily obtained by inoculating tubes of saccharose-potato-agar with any of the mill products and keeping at 130°-140° F., or by placing a flask of mixed juice in a water bath at the same temperature for from 6 to 24 hours. Though no increase of bacteria may be observed for perhaps six hours, during the following hour they may multiply two or three hundred times, so rapid is their growth when once they start. Very little change is noticeable in the appearance of the juice, so that the presence of the organism can be detected only by the aid of the microscope, though decomposition would be shown by chemical analysis.

"It grows vigorously in any mill juice lighter than 50° Brix, at any temperature between 100° and 170°, destroying cane sugar and diminishing the alkalinity; but at higher temperatures its activity ceases, though boiling, or even superheating at 260°, does not kill its spores.

"Lime in moderate quantities, up to 5% N. alkalinity, greatly assists it, while its growth is only slightly hindered by ten times this proportion (50% N. alkalinity)."

While the above report was not made on conditions in Hawaii, and so far as the writer is aware, no investigation has been made here to detect the presence of such an organism, there are strong indications that some such high temperature organism is present in our mills.

In Mr. Walker's work as reported last year the temperature of the juice did not drop below about 170° and no destruction of sugar took place. Mr. Fries does not give the final temperature in his report, but it is probable that with his

equipment the temperature fell to a point below 170°, particularly in the tests that extended over the longer period of time. It was in these tests, extending over a longer period, that the large drop in purity when no preservative was used was encountered. Some of the results found by Mr. Iyer, and Mr. White's figures, as well as a number of observations made by the writer, would be explained by the presence of such an organism.

The work that has been done on this subject in the last year or two indicates that juices held over must receive careful attention and that considerable losses, particularly in mills running in the daytime only, are liable to, and probably often do, occur through deterioration of such juice.

In the course of an investigation of the value of some antiseptic solution for the preservation of juice at this Station it was noted that mixed juice could not be preserved for twelve or eighteen hours even with formalin in the proportion of 1 to 2000. Clarified juice could be kept for several days with this strength of formalin. The difference is probably in the degree and quality of the infections. Had the clarified juice been in an active state of decomposition it is improbable that this amount of formalin would stop the deterioration entirely.

Mr. Walker has contributed the following paper on the deterioration of mixed juice to which no preservative has been added in one hour's time:

Tests on Deterioration of Raw Juice at Pioneer.

"A sample of mixed juice taken as it was leaving the mills, was cooled, kept in a covered bucket and polarized every hour. As a matter of precaution against any difference that may be due to lead, two grams of lead to 100 cc. of juice were used for each sample. These tests were made by Mr. B. B. Henderson.

Hours	0	1	2	3	4	5	6
February 19	50.5	50.3	50.3	50.2	50.0	49.9	48.8
" 24	52.1	52.0	51.9	51.8	51.5	51.3	51.1
" 26	55.0	55.0	55.0	54.9	54.5	54.1	53.8
" 27	63.6	63.6	63.5	63.3	63.1	63.0	62.8
" 28	53.3	53.3	53.2	53.0	52.9	52.8	52.8
Average	54.90	54.84	54.78	54.64	54.40	54.22	53.86
Drop		0.06	0.12	0.26	0.50	0.68	1.04
Drop in 1 hour		0.06	0.06	0.14	0.24	0.18	0.36
% of total polarization lost in 1 hour		0.11	0.11	0.25	0.44	0.33	0.66

"These tests were repeated in another series, taking the loss during the first hour only. Samples of mixed juice were taken as before, and polarized immediately and after standing one hour. No preservative was used either in this or in the preceding tests. Below are the averages of 21 tests made on separate days during the season:

Polariscope reading immediately	55.44
Polariscope reading after one hour	55.38
Average loss in reading	0.06
Average loss % total polarization	0.11%

"Four samples out of the 21 showed a slight gain, the maximum being 0.03, or within the limit of experimental error.

"Four samples, which happened to have an extra high initial polarization compared to the others, lost over 0.05 in polariscope reading in an hour, the maximum drop being from 61.54 to 61.20. Eliminating these four samples the average loss in reading of 17 samples was only 0.02, or 0.04% of the total polarization.

"These tests prove very conclusively that in the case of this particular mill at least our fears of high losses by deterioration at the mill were groundless. The loss in one hour is so slight that it requires the average of a large number of tests to prove its existence. A liberal time allowance for the passage of the average juice from the mill to the heaters would be fifteen minutes, and, since any loss due to bacterial or yeast infection increases in rate as the organisms multiply, the deterioration of our mixed juice during the first fifteen minutes can be **at the most** less than one-fourth of that found in the first hour or less than 0.03% of the total sucrose in the juice."

This committee was also requested to report upon "The discrepancies sometimes found between the reported composition of the final molasses before shipment and after arrival at the Coast."

On inquiry your committee found that with the exception of that shipped from one plantation, molasses that is shipped to the Coast is sampled before leaving the Islands and payment is made on the analyses of these samples. Any deterioration of the molasses while en route, therefore, does not affect the discrepancies referred to in the instructions given this committee. The differences are due either to deterioration of the samples or to differences in analyses in the different laboratories.

The following figures were furnished by Mr. J. W. Waldron, covering 18 shipments of molasses from Honokaa:

	Total Sugars.
H. S. P. A. Experiment Station	43.6
Buyers' chemist in San Francisco	41.5
Difference	2.1

In the above case the molasses is shipped in drums and is thinned to a considerable extent, so that it can be handled. Samples of this molasses have deteriorated very rapidly in this laboratory, and a part of the above differences are probably due to deterioration of the samples.

Mr. G. P. Wilcox of American Factors, Ltd., writes as follows:

"Replying to your letter of January 3rd we beg to advise that the only records that we have of the outrun of molasses shipments on arrival at destination is a report from our San Francisco office showing the total sucrose and glucose contents. It has been our experience that the analyses in this respect agree very closely with those obtained from the Experiment Station at the time of shipment. In fact, we have only one very noticeable discrepancy. These analyses were:

	At San Francisco.	H. S. P. A.
Sucrose	31.80	33.00
Glucose	18.07	19.00
Total Sugars	49.87	52.00

The following are the figures for shipment from Waianae Plantation, secured through the courtesy of Mr. Dowsett:

	1917.		1918.		1919.	
Analyses at	Sucrose.	Glucose.	Sucrose.	Glucose.	Sucrose.	Glucose.
Plantation	34.39	13.98	34.47	14.17	34.97	14.33
San Francisco	34.35	13.68	33.39	13.75	33.97	13.74
Difference	0.04	0.30	1.08	0.42	1.00	0.59
Total difference	0.34		1.50		1.59	

Mr. Swezey's Report on Attendance at the Annual Meeting of the American Association of Economic Entomologists.

HONOLULU, T. H., February 25, 1921.

The Director,
Experiment Station, H. S. P. A.,
Honolulu, T. H.

DEAR SIR:—I hereby report on my attendance at the annual meetings in Chicago, December 27, 1920, to January 1, 1921, of the American Association for the Advancement of Science, the American Association of Economic Entomologists, and the Entomological Society of America.

All of the numerous sections of the American Association for the Advancement of Science were held in different lecture halls of the various departments of the University of Chicago and were very largely attended. The two entomological societies met under Section F (zoological sciences) of the American Association for the Advancement of Science. There were well over one hundred entomologists in attendance at the sessions of both entomological societies, some of the more noted among them being Dr. L. O. Howard, C. L. Marlatt, A L. Quaintance, A. F. Burgess of the U. S. Bureau of Entomology; E. D. Ball, Assistant Secretary of Agriculture; J. M. Aldrich of the U. S. National Museum; C. T. Brues and W. M. Wheeler of the Bussey Institution; V. L. Kellogg of the National Research Council; E. P. Felt of the New York State Museum; Arthur Gibson, Ottawa, Canada; P. J. Parrott, State Entomologist of New York; W. C. O'Kane, State Entomologist of New Hampshire; Professor Herbert Osborn of Ohio State University; H. A. Gossard, State Entomologist of Ohio; J. G. Sanders of Pennsylvania; J. J. Davis of Indiana; Wilmon Newell, Florida; S. A. Forbes and J. W. Folsom of the University of Illinois; A. L. Melander, Washington; W. E. Hinds, Alabama; Glenn W. Herrick and W. A. Riley, Cornell University.

The Entomological Society of America, of which Dr. L. O. Howard was president and Dr. J. M. Aldrich secretary, had sessions both forenoon and afternoon for two days. Eighteen papers were presented, usually being followed by discussions. Some papers had to do with life histories, others with structure, and some with parasite relations, while others dealt with geographic distribution. In most instances they dealt with insects of more or less economic importance in some part of the United States.

One paper dealt with Bacterial Symbionts of Blattidae. From the author's illustrations exhibited, the organisms treated of as occurring in roaches, and which he called Bacteroids, are similar to the yeast-like organisms which have recently been found to be abundant and always present in our sugar cane leafhopper, as well as in all of the native leafhoppers of the Delphacidae which have been examined. This is a line of interesting investigation, as little is

known yet of the role these organisms play in their host insects,—whether detrimental or not. A few other kinds of insects have been found to contain them.

Professor Osborn had a paper on some leafhoppers of forest trees, and Z. P. Metcalf gave a review of the Fulgorid leafhoppers of North Carolina, of which 270 species are now known.

Dr. Howard gave a lantern-slide exhibition illustrating his last summer's visit to Europe. He showed pictures of the many entomologists visited and gave many interesting incidents of his trip, which was mainly to England, Belgium, France, and Italy.

The American Association of Economic Entomologists, of which Wilmon Newell was president and A. F. Burgess secretary, had both forenoon and afternoon sessions for three days, following the meetings of the Entomological Society of America and attended by mostly the same entomologists. Thirty-five addresses and papers were presented, many of them illustrated by lantern slides. One of the sessions was held jointly with the American Phytopathological Society, the purpose of the joint session being a symposium on "Dusting as a Means of Controlling Injurious Insects and Plant Diseases." This brought out that dusting is the more profitable method to use when conditions and circumstances permit its use. More area can be covered in the time and the machinery used is not so expensive as where spraying is employed. Dusting has been used successfully against the cotton boll weevil in the south, also against curculio and codling moth in Michigan. In the latter instance, apple scab was not so well controlled by the dusting method.

I can not attempt to review all of the papers presented, but will make some mention of some of the prominent ones of the regular sessions.

The European corn borer came in for a considerable part on the program. It is a moth whose larva bores into corn stalks and a number of other plants. It is now considered that it was introduced to eastern United States by importations of broom corn from Europe. It has been known in eastern Massachusetts but a few years and has already spread into New York state, where the infested area now covers 22,000 square miles, and the spread is about twenty-five miles per year. Some isolated places in western New York and northwestern Pennsylvania are considered to have occurred from recent importations of infested broom corn. Recent observations show that it is not to be considered such a serious pest, although large appropriations are asked for to combat it and check its spread. It is found that corn in low places is most subject to infestation and that there the common extent of infestation was twenty-five per cent of the stalks, while a thirty per cent infestation was necessary to cause commercial loss; and a ninety per cent infestation even is not a total loss of crop. Control work has developed a crushing machine for putting through corn stalks, stubble, etc., to destroy larvae and pupae therein. One machine can handle twelve to fifteen tons per day. An oil-spraying burning machine has been devised, also, capable of burning a strip twelve feet wide, and to treat twelve to fifteen acres per day. Work has also begun in introduction of parasites for the corn stalk borer.

Corn aphis was reported as a bad pest on corn in Kansas, where it is found

necessary to plant early, May first, to avoid injury. This aphis is the same as infests corn here, though not so seriously as the corn leafhopper. It is likely that here some special planting season could be found that would be most favorable to avoid injury by this pest.

Several papers dealt with a leafhopper occurring on potatoes, in connection with a condition of the leaves called "tipburn." Experiments have proved that the tipburn is caused by this leafhopper and that it could be controlled by spraying with Bordeaux, which acted as a repellant rather than an insecticide. Nicotine sulphate and kerosene emulsion were found ineffective against this leafhopper.

In a report of control work with the pecan case bearer in Texas, is an example of great loss produced suddenly by an insect probably always present. This is a tiny moth larva which is found on pecan trees. In 1920 they attacked the nuts, when very small, to such an extent that there was almost a complete failure of the crop, whereas the crop in Texas for the previous year was 1000 cars. Experiments showed that spraying with arsenate of lead gave ninety per cent protection.

Among apple insects, the codling moth received attention in the way of discussion of recent experiments in its control. It is a pest that the apple grower always has to reckon with. Marketable apples can not be grown without spraying at the proper time, and often two or three times are necessary, determined by conditions prevailing in the locality, and differing for the different apple-growing sections of the country. For instance, the entomologist from Washington stated that there one spraying when the calyx was still open, together with a later thinning of any wormy young growing fruit, was sufficient to produce nearly one hundred per cent sound fruit.

The green Japanese beetle situation in New Jersey continues to increase in seriousness. Mr. C. H. Hadley, at present in charge of control work, gave an account of the present status of the work. The beetle is continuing its spread in spite of very extensive measures employed to prevent it. A zone surrounding the infested area is kept dusted or sprayed to endeavor to hold the beetle within bounds. This pest as compared with our *Anomala* differs in its method of attack. The adult beetles do the damage to crops by feeding on the foliage like our own Japanese beetle (*Adoretus*). The grubs in the ground do not injure crops by eating the roots as our *Anomala* did in the cane fields. Their grubs are more trash feeders and do not injure crops. They occur very abundantly under litter and roadside trash. Immense quantities of the beetles and also the grubs are being collected and all known methods of using insecticides against them are being employed, but still the infested area increases annually at a rapid rate. This region in New Jersey is near the Delaware River a little above Philadelphia. In 1920, in spite of attempts to prevent it, the beetles crossed the river over into Pennsylvania and became established to some extent. On this account an area there of about seventeen square miles is quarantined. An attempt is being made to find in Japan parasites which may be introduced to help check this pest, two men being employed in that work at present. They are encouraged in this by our experience in Hawaii in introducing *Scolia* as a parasite on *Anomala* grubs, which it has so effectively checked.

In connection with the cotton boll weevil, some data relative to the value of birds is of interest. In Texas, quail are abundant and search the cotton fields for insects, which are their normal diet. Examination of quail crops and stomachs has shown ninety-two per cent of them to contain cotton boll weevils, and as high as forty-seven of these beetles per quail. And yet in a state where there is an annual loss of $150,000,000 due to the boll weevil they fail sufficiently to protect the quail which destroys such great quantities of the weevils. The present protection laws allow a hunter to bag up to thirty-five quails per day. The value of the quail as a source of sport or food is small compared to its value as an insect destroyer. Many other birds (even game birds) could be placed in the same category.

A lantern slide exhibition was given by myself of the important sugar cane insect pests in Hawaii and their introduced parasites, together with some account of these. I also presented a paper on "Recent Insect Immigrants in Hawaii," in which I listed and gave notes on twenty-eight foreign insects which were observed for the first time during 1919 and 1920. Most of these are of no economic importance; some are beneficial, being parasites; only a very few are injurious or likely to become pests or to require any control measures being employed.

Along this line, Mr. E. R. Sasscer gave a paper on "Important Foreign Insect Pests Collected on Nursery Stock in 1920." They are always finding new pests on imported plants, which shows the importance of establishing more effective quarantine measures. One whole afternoon was taken up with papers and discussions relative to the present methods of quarantine, the special insects quarantined against, and plans for further extension of such quarantines.

Of interest in this connection was an account of the recently discovered area in New Jersey infested by the gypsy moth. This is on the Duke's Farm Company at Sommerville, where blue spruce trees from Holland were imported and planted several years ago. Later (1913) some of the trees were removed and shipped to various parts of the state, some even outside the state. Recently the blue spruce grove was found to be infested with gypsy moth, and tracing the shipments of trees made from there in 1913, eight other places, within an area of ninety square miles were found infested by gypsy moth apparently from this source. It is now considered that all this has resulted from there being one or more gypsy moth egg masses in the original lot of imported blue spruce trees planted by the Duke's Farm Company. At great expense attempts are being made to eradicate the pest in these places.

Strenuous efforts are being made by the Federal Horticultural Board to keep the pink boll worm from gaining a permanent foothold in Texas, by quarantine work at the points of entry on the border line between Mexico and Texas. Cotton and cotton seed are prohibited, of course, and they have immense fumigating sheds capable of fumigating fifteen freight cars at once, to fumigate all freight cars coming across from Mexico. These are at Brownsville, Laredo, and El Paso. Fourteen thousand freight cars are fumigated annually. Passengers are also inspected, as a good many Mexicans go up to Arizona to pick cotton and for other labor, and have been found carrying cotton pillows, etc., amongst their

luggage. Avocadoes are prohibited at these places also, and they find the Mexicans smuggling them across in many ways. They have been found concealed in loaves of bread, and hidden in or beneath women's clothes.

One evening session was held, devoted to the Apiary Section, at which was a symposium on "Foulbrood," and other papers on problems of the industry. A new phase of the bee-keeping industry is practised by a bee-keeper in the suburbs of Chicago. He supplies hives of bees to the gardeners who grow cucumbers under glass, for the purpose of having the cucumber flowers pollenized by the bees. One to ten hives are supplied, according to size of greenhouse in use.

On one evening an Entomologists' dinner was held at the Hotel Sherman. More than one hundred entomologists participated. Representatives of various entomological societies were called on for brief remarks. I represented our local entomological society and was the most distant member in attendance.

On one other evening occurred the Annual Osborn Dinner, at which twenty-five of us, who had at some time studied entomology under Professor Herbert Osborn, sat at table with him. It is worthy of note that so many of the entomologists in attendance at the meetings, and holding important positions all over the country, should at some time have had work with Professor Osborn of Ohio State University. After dinner each one present was called on to give some account of himself, with special reference to recent activities in entomological work, and a very interesting hour was spent.

On my return trip I visited entomologists at the Sugar Station at Audubon Park, New Orleans; at Phoenix, Arizona, and at the Citrus Experiment Station, Riverside, California. Mr. E. R. Barber at Audubon Park told me of his work in the introduction from Cuba of a Tachinid parasite for the sugar cane moth borer in Louisiana. A small number of puparia had been obtained in 1919 and from them the parasite had become established in the cane field at the Station. In 1920 a number of the cane growers contributed to a fund for further introductions of the parasite. Mr. Barber with four assistants went to Cuba for a few months in the summer and collected over seven thousand puparia of the parasite. There was a very good percentage of emergence from these at the Station, and the parasites were distributed to all of the planters who had contributed to the fund. The chances of the parasite becoming permanently established were considerably lessened thereby. But each planter was insistent that he should receive something for his money contributed, which necessitated their division into such small colonies that they may prove to have been inadequate. It yet remains to be seen whether the project was successful.

At Phoenix, Arizona, is a large area of land irrigated from the Roosevelt Dam. In 1920 it was mostly in cotton, a large crop being obtained. A longer staple variety is grown and a better yield per acre is obtained than in the Gulf States. The State Entomologist told me of their efforts to protect the cotton regions in Arizona from a weevil, which is related to the cotton boll weevil, which has been discovered attacking a native cotton growing in the mountains of Arizona. Scouting is carried on to eradicate this native cotton where it grows along stream beds from seeds carried down from the mountains by these mountain streams. So far the weevil has not appeared in the cultivated cotton fields.

The Citrus Experiment Station at Riverside, California, is a part of the University of California. Mr. Quayle, the entomologist in charge, has been working of late on control of codling moth on the walnut, a new food habit for this pest. Mr. Stahl, of the U. S. Bureau of Entomology, is stationed here and is carrying on investigations with the sugar beet leafhopper. It is a much smaller insect than our sugar cane leafhopper and does not occur in such great numbers as our leafhopper has at times, but it takes only a few to cause great injury to a beet field, for they transmit a disease called "curly leaf," which very much cripples the growth of the beets. This disease occurs on certain native weeds on which the leafhoppers feed for a part of the year, and is transmitted to the beets when fed on by leafhoppers which have fed on the diseased weeds. This leafhopper has several parasites which would perhaps keep it sufficiently controlled if their actual feeding on beet leaves was the only thing concerned. But in their transmitting the disease such a small number are necessary to accomplish this that it will require almost complete extermination of the leafhopper to accomplish much benefit, or the eradication of the weeds that are also affected by "curly leaf" disease. This is perhaps less possible than the former. They have a very complicated problem. One line being followed is in the production of immune varieties of beets.

On the trip I also visited several large museums to see what is being done in entomology: Field Museum at Grant Park, Chicago; Matthew Laflin Mills Museum at Lincoln Park, Chicago; Museum of the California Academy of Sciences, Ocean View Park, San Francisco, California; Southwest Museum at Los Angeles, California; also the Entomological Laboratories of the University of California, Berkeley, California.

Respectfully submitted,

O. H. Swezey,
Entomologist.

The Use of Sugar Cane Molasses as a Fertilizer.*

M. de Sornay, the Director of the Agricultural Research Laboratory of the "Colonial Engrais Chimiques" at Port Louis (Mauritius), draws attention to the importance of sugar cane molasses as a fertilizer. The market value of this substance is very small, and the results obtained with it in Mauritius and numerous cane-growing districts leave no doubt as to its efficacy as a fertilizer. It is used after having been thrown on the dung-heap for the purpose of hastening its decomposition, or mixed with sugar-refining residue and ashes, that is to say, in the form of an actual compost known as "saccharogene," which is thrown in a

* From The International Review of the Science and Practice of Agriculture.

concentrated condition into the trench before planting, or placed at the base, or spread between the rows.

According to the experiments mentioned by M. de Sornay, the increase in yield thus obtained varies from 5 to 10 per cent.

M. de Sornay has investigated the reasons for the increase in yield, small though it is, obtained from sugar canes that have been manured with molasses. He carried out most careful experiments with a view to determining whether the presence of sugar was favorable to microbial action in the subsoil, and to the fixation of nitrogen, and how far, under the influence of the disappearing sugar, the elements of the soil became disintegrated and transformed into more soluble substances. The results which he obtained were, however, not sufficiently conclusive to permit of his attributing the efficacy of cane molasses to any of these causes. In short, its utility does not seem to depend upon its potash content. Although M. de Sornay has thus been unable to solve in a satisfactory manner the problem he set himself, he does not deny the efficacy of molasses as a fertilizer.

[R. S. T.]

Forty Years of Boiler Explosions.*

The Locomotive, the house organ of the Hartford Steam Boiler Inspection and Insurance Co., contains in its October issue a summary of that company's statistics on boiler explosions that have taken place in the last forty years. The total number of explosions covered is 14,281, in which 10,638 lives were lost and 17,085 persons injured. These figures are not, of course, complete, especially in regard to the number of boilers in use, for no means are available of securing complete records of boilers throughout the country. They may, however, be taken as fairly representative and indicative in a general way of conclusions that would be drawn from a more comprehensive survey.

The figures comprising this summary have been put into graphic form, as in this way their significance is more readily grasped. It should be remembered, however, that charts of this nature must be taken in a very general way. That is, the "saw-teeth," or sharp, extreme changes, are not in themselves of much importance. The general trend of the lines, however, shows more clearly than figures possibly can, just what the situation is.

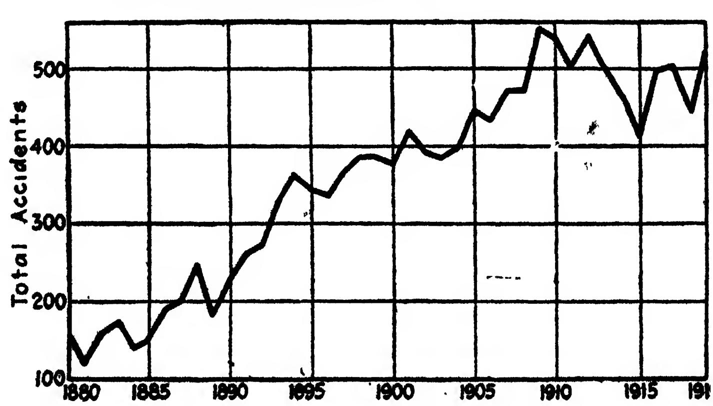


Fig. 1. Total explosions per year.

Fig. 1 shows the rise in the number of explosions per year since 1880. This chart must be considered in the light of the obvious fact that the number of boilers in use has increased steadily; but whether that increase has been less than, equal to, or greater than the increase in the number of accidents cannot well be determined. However, it will be noticed that from 1909 on, a slight and widely varying, yet decisive drop, is apparent; and it scarcely seems possible that the number of boilers in use since 1909 could have decreased or even remained constant. That it has, on the other hand, increased, is a reasonable assumption. This, of course, leads directly to the conclusion that the ratio of the number of accidents to the number of boilers in use has decreased since 1909.

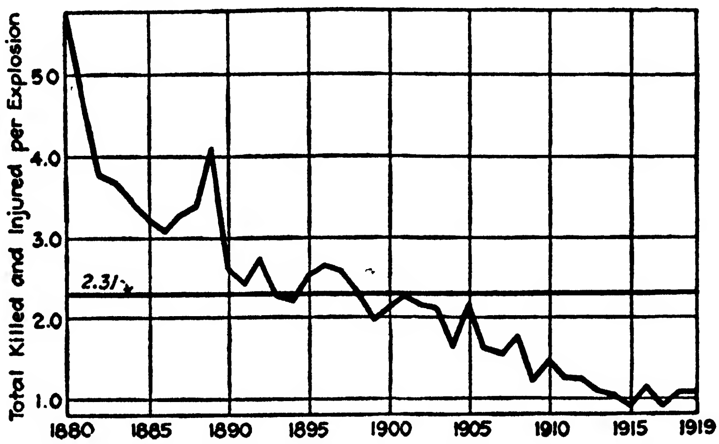


Fig. 2. Total killed and injured per explosion.

Fig. 2 shows a very marked decline in the number of persons killed and injured per explosion. The line marked 2.31 represents the average of the totals for each year. It can be seen that whereas in 1880 more than five persons were killed or injured in each accident, this figure came down to about one in 1919. This curve is of especial interest because of its very pronounced downward trend and because of possible speculation as to its cause.

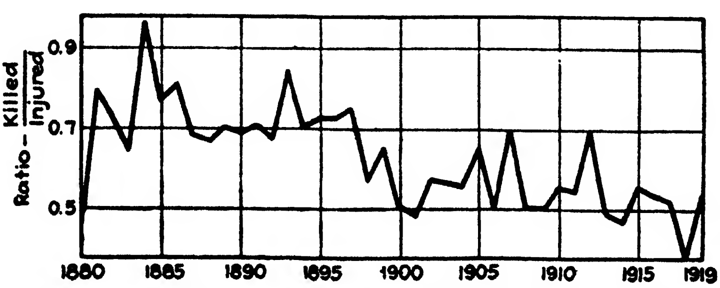


Fig. 3. Ratio between killed and injured.

Fig. 3 represents the changes in the ratio between those killed and those injured in each explosion. While this curve does not fall so rapidly as that in Fig. 2, still it does drop appreciably. It shows that at first there were almost as many killed as injured, and that now the killed are about half of those injured.

Taken as a whole, these facts are rather gratifying than otherwise. Though they are incomplete, they indicate with a fair degree of certainty a trend in the

right direction. The apparent decrease in explosions relative to the number of boilers in use, the reduction of casualties per explosion, and the smaller proportion of fatalities point to increasing care in the construction and operation of boilers.

[W. E. S.]

Installation of Battelle's Plantation White Sugar Process in the Central Jovero, Dominican Republic.*

A large factory to be known as the Central Jovero is being erected at Samana Bay, Dominican Republic, by the Honolulu Iron Works for the American Dominican Sugar Co., of New York, the capacity of this plant being 1500-2000 tons per day. It is of interest to note that the Battelle process for the manufacture of a plantation white sugar (quite equal in quality to the "standard granulated" of the American beet factories) will be employed. This process, it will be remembered,[1] consists briefly in boiling the cane juice with an excess of lime (the "glucose" thus being destroyed), and applying the carbonatation process, after which the light-colored juice obtained is concentrated and boiled to grain in the usual way. A feature of this method of working is that the sugar ordinarily lost in the molasses is recovered by means of the Steffen process, an increased recovery of about 5 per cent being thus obtained.

Mr. E. Erle Battelle (who will be in charge of the El Jovero plant) is reported as having stated that: "It is understood the cane contractor will deliver not less than 200,000 short tons of cane per year to our mill by ox carts or loaded into our railroad cars at sidings. The yield of sugar will not be less than 12 per cent or 24,000 tons per year of granulated sugar, of which 12,000 tons (50 per cent) will be delivered to the cane contractor as his portion of the product and as full payment of his delivered cane, and the remainder of 12,000 tons granulated sugar to be our share of the product. The estimated costs and charges, including labor, packages, supplies, railroad operation and repairs, repairs equipment, administration costs, and fixed charges and depreciation should be 1.5911 cents per pound sugar produced and 3.1822 cents gross per pound cost to us. This outside cost for our granulated sugar, before dividends, of 3.1822 cents f.a.s. will permit us to deliver, duty free, at Atlantic ports of the United States at the additional cost of 0.4579 cents for insurance and freight and 1.36 for full U. S. duty, or a total cost on the American market of 5 cents per pound."

[R. S. T.]

* New York Record, October 8, 1920, reprinted in International Sugar Journal, 22:708, 1920.

1 See I.S.J., 1912, 163; 1913, 47, 535; 1914, 181, 484; 1915, 357; 1919, 577.

The Mosaic or Mottling Disease of the Sugar Cane.*

THE MAIN FACTS OF THE CASE TO DATE.

By C. A. BARBER.

Mosaic of the sugar cane is perhaps the disease of the hour. This is not necessarily because it is the most widely distributed or the most important, but rather because two parts of the United States, noted for the excellence and profusion of their publications on agricultural matters, are undergoing a somewhat acute phase of anxiety on account of it. In Porto Rico it has been noted sufficiently long for a fairly detailed estimate to be made of the losses attributable to it; although it may well be doubted, in view of the facts presented in the paper on Root Disease in that island in the last number of this journal, whether at some future and calmer moment, the figures given may not be regarded as the reverse of conservative, as they are now claimed to be. And, in the United States, the officers of the Agricultural Department, alarmed by these figures, have with characteristic energy investigated the matter, and, within a year of the discovery of the disease there, produced a mass of evidence that it has caused serious losses during recent years, and published broadcast the means by which it can be kept under control.

Our attention was first directed to this disease, possibly long familiar to us in the cane fields of the tropics, by a lively controversy in our contemporary, the Louisiana Planter, in which the scientific workers in Porto Rico and Louisiana and to a less extent in Hawaii on the one side, and those in Cuba and Argentina on the other, became involved. While it is said to be a serious disease in Hawaii, it has been known there since 1910 and is under control; in Porto Rico it was first detected in 1915, and is rapidly enveloping the whole of the island and causing much loss; in the continental United States it was definitely named in 1919, and was then found to have spread to all of the sugar-growing States in the south; in Cuba it had been noted by responsible officers 18 years ago, and is of local distribution and minor importance; while in Argentina it has been present for at least 15 years, and is now so universal that it is almost impossible to find a single plant free from it; here, again, it is not regarded as serious.

With these various and conflicting opinions before us, we watched the contest and "sat on the fence," having no means of judging the validity of the arguments on either side. But a series of exhaustive papers have recently been published by American workers in Porto Rico and the United States, and we have been able to form more definite conclusions as to the real state of affairs. We propose in this article to lay these conclusions before our readers, without in any way claiming to be arbiters in such matters as are still in dispute. We merely intend to try and summarize the more important aspects of the question, as detailed by the responsible officers on the spot, whose attainments are unquestioned and whose opinions are worthy of the most careful consideration.

* The International Sugar Journal, 23:12-19, 1921.

It may be well, in the first instance, to give a short résumé of the controversy as presented by the articles in the Louisiana Planter during the past year, the figures in brackets giving the date and page of each of these.

(1) J. R. Johnston, a recognized authority on cane diseases in the New World and until recently Pathologist at the Central Experiment Station in Cuba, opened the ball (July, 1919, p. 43) with a reference to recent articles in the Havana papers which indicated that the Mosaic disease was present in that island. He detailed the main character of the disease in Porto Rico as follows: Its cause was unknown, but it was not a simple chlorosis; it was injurious and transmitted by cuttings; the soil was incapable of transmitting it, and it was incurable; its attacks differed in different varieties, from immunity to heavy infestation, from serious damage to considerable resistance; it might remain harmless for a series of years and then suddenly leap into prominence and spread rapidly. The disease appeared to be identical in Porto Rico and Cuba, as well as in Hawaii and Java. where it had been known as Yellow Stripe for some time; it was therefore advisable to watch it carefully in Cuba.

(2) This paper of Johnston's provoked a reply from R. M. Grey, Superintendent of the Harvard Experimental Station, Cienfugos, Cuba (August, 1919, p. 90), contesting Johnston's facts. Grey stated that he had found the disease 18 years before and had kept it under observation for 14 years. He had carefully examined it and, as the result of innumerable observations and experiments, considered that it did no damage; he further stated that it was not incurable, and claimed that he had repeatedly succeeded in eliminating it by improved cultural methods; he had never found a case where it was fixed and permanent; "mottling disease causes absolutely no injury in Cuba, and if root disease and leaf rot could be eliminated we might forget it."

(3) The Editor of the Louisiana Planter (August, 1919, p. 82) drew attention to Grey's paper, and quoted the case of frog-hopper in Trinidad, where far less injury was caused where the earth had been properly worked: and he also drew attention to the various alarmist predictions regarding borers which had not materialized and the divergent views held by scientific officers as to the usefulness, in fighting them, of burning the trash.

(4) As was natural, this brought Porto Rico into the field. F. S. Earle, Expert in Sugar Cane Diseases, of the United States Office of Sugar Plant Investigation, and now working in Cuba (September, 1919, p. 167), regretted the tone of recent articles in the Louisiana Planter. Considering that the behavior of the disease was contradictory, remaining harmless for years and then suddenly springing into activity and causing widespread loss, it was the best policy to attack it while it was in the quiescent stage. Considering Grey's claim to have eradicated it by cultural methods, he suggested that that worker might have confused true mottling with the often similar attacks of insects and fungi. The disease was now widely spread throughout continental United States, and it would be unfortunate if planters there were lulled into a false sense of security. The Editor added a note to this letter maintaining the view previously expressed by him and referring to the campaigns against the cotton boll weevil and yellow

fever, where success had, after enormous sums of money had been expended, been obtained through comparatively simple side issues.

(5) Grey, declining to enter into a discussion on the subject, simply stated (September, 1919, p. 199) that he had made no such mistake, and had cured the actual plants, identified by the United States experts as suffering from the Mosaic disease, in 116 days, and others equally badly affected in 59 days. He suggested that, from what he had read, the weather and other natural conditions in Porto Rico seemed to be more severe than in Cuba.

(6) Lastly, G. L. Fawcett, Botanist to the Agricultural Department in Argentina, a consistent student of sugar cane matters, wrote (January, 1920, p. 39) an article discussing the effects of Mosaic in that country, as probably of interest. He had noted the spotting of the leaves on reaching Argentina four years before, but, in the absence of apparent damage, had turned his attention to the really serious sugar cane diseases. Recently, this spotting had been identified by Porto Rican and Hawaiian experts as Mosaic. The disease was known 15 years ago in Jujuy province, and it was now practically impossible to find a single plant in Argentina not infected, except in a small area in the south of Salta, and that the infection was doing no apparent damage. The thick canes of the country had, it is true, been driven out, but he did not regard Mosaic as the cause. This was rather due to the difficulty of such varieties in rapidly establishing themselves after harvest before the cold weather set in, thus suffering from decay of the roots and stubble before the spring. Various Java seedlings, while freely infested with Mosaic, were better able to stand the adverse climatic conditions and the Mosaic did them no harm, as evidenced by the tonnage obtained. Fawcett, however, disagreed with Grey in Cuba in one particular, in that he found better cultivation of no avail against Mosaic, nor had he ever seen a plant recovering from it when once attacked.

This controversy has been of great value, and justifies the conclusion that the disease is in some way dependent on local conditions, so that its behavior is contradictory in different countries, as is so often the case with cane diseases. Like other diseases, it is capable of long periods of quiescence and harmlessness, but in certain circumtances may suddenly increase rapidly and become a serious infectious disease. And, such being the case, it is the only wise course to search for it everywhere, and when found to keep it under observation, meanwhile taking note of the methods which from time to time and place to place have been found to keep it in check. Thus, if it becomes dangerous, it can be at once treated with full knowledge so as to limit its harmful character. It might be mentioned, lastly, that the discrepancies brought out in this interchange of views in the Louisiana Planter should be cleared up, especially the claims that Mosaic can be influenced by better cultivation in Cuba.

In the following notes on Mosaic a number of papers have been consulted, the most important of which are mentioned below: these are such as have come our way. It is claimed in Hawaii and elsewhere that Mosaic or Mottling is identical with the Java Gele Strepenziekte (Yellow Stripe), first mentioned by Musschenbroek in 1892 and subsequently studied by a number of other workers in Java. Lyon of Hawaii gives the following distribution of Yellow Stripe:—

Hawaii, Fiji, Australia, New Guinea, Java, Philippines, Egypt, to which may be added Porto Rico, San Domingo, Cuba, Argentina, St. Croix, and lastly (I.S.J., 1920, pp. 669 and 670) Trinidad and Jamaica. It has in these places accumulated a multitude of names, of which Mottling or Mosaic seem to be the best. The latter name seems most likely to survive, because it is the name current in the United States and at present in Porto Rico, is descriptive of the disease and especially, indicates its relationship to the mosaics of tobacco and other plants.

The following are some of the main characters: a full description is impossible within the space available and will not be attempted. The chief character is of course a mottling or striping of the leaves caused by the occurrence of dots and short stripes of lighter green and, somewhat later, white, scattered over the darker green background of the normal leaf: these increase in number, coalescing in various ways so that the normal green color becomes the exception and the whole leaf takes on a pale, often yellowish tint. A great variety of patterns is thus produced on the leaf, and these are distinguishable from those caused by fungi in that the invaded tissue does not die and turn brown, and from the spotting by sucking insects in that these are almost invariably surrounded by a pale almost circular area: the larger spots in Mosaic are invariably elongated. It is distinguished from the various forms of non-infectious chlorosis by the distribution of the light coloring which, in the latter, is usually local: in Mosaic the whole leaf is infected excepting sometimes at commencement. This affection of the main feeding organs of the plant, whereby the color bodies are killed, is naturally accompanied in most cases by feebler growth, and the plants become stunted. The new internodes are shorter and thinner, and, at a later stage, show lesions or cankers on the surface, become less juicy and even pithy, until finally no commercial canes are produced and the field has to be abandoned. This last stage usually occurs in the third year from planting, but this will depend upon the relative power of resistance of the variety. The plants do not appear, however, to be killed by Mosaic: they merely become unprofitable from the crop point of view.

The disease is passed from generation to generation and field to field primarily by the sets, and as, once attacked, the whole of the tissues are affected, no part of a diseased plant can produce healthy offspring. But the disease is also highly infectious: a secondary form of transmission is quite obvious, for diseased plants rapidly contaminate all that are near to them and also, in many cases, appear to be able to do so over very considerable distances. It has been definitely proved that this secondary infection does not take place through the soil, and, once an abandoned field is plowed up and none of the old shoots allowed to develop, perfectly healthy canes can be grown if taken from plants in their turn healthy. This negative action of the soil has been proved in various ways again and again, one experiment being to place healthy sets in pots from which diseased plants have just been removed. The mechanics of secondary infection has not to all appearance been definitely worked out as yet, but there is the strongest evidence that insects of the sucking kind, often powerful fliers, are concerned in this natural inoculation. Their action appears to be most effective, and yet all attempts to carry out artificial inoculation appear to have failed or, if they have

succeeded, only so in the rarest cases. Insect carriers further explain the observed facts, and aphides and frog-hoppers are suspected, acting presumably just as they do in the allied curly-top disease of the beet and some other diseases. In these cases a very small amount of virus is sufficient to infect a great many plants, and this may well be the case with cane Mosaic, as the spread of the disease by secondary infection is remarkable for its rapidity. The period of incubation appears to be from two to three weeks and the disease appears within six weeks or two months of planting.

No organism of any kind has been found in the tissues to which the disease can be attributed, and the view generally expressed is that we have here to do with an ultra-microscopic organism or perhaps a perverted enzyme,—which is, after all, rather a confession of failure, just as in the old days when an obvious fungus was not found in the tissues of a diseased plant it was often suggested that bacteria were at work. But the behavior is so like that in cases of demonstrable infection by fungi or bacteria, and the number of similar unexplained epidemics is so great, that there is much to be said for the theory. This is one of the many riddles which phytopathologists have to solve. There are quite a number of diseases, frequently rapidly spreading and very deadly, for which no adequate cause has been found. We need only mention the sereh disease of the sugar cane, the spike disease of sandal, peach yellows and curly-top in the beet. At first it was frequently held that the disease was induced or at any rate largely assisted by deterioration, another refuge for the destitute, or by bad weather, soils, manuring, cultivation, and this last has received some encouragement from the statements of Grey in Cuba. But, for the disease in its destructive form, the very complete study to which it has been subjected has knocked away these props one by one, till it is generally conceded that to no single one or combination of them can the disease by any chance be attributed, and there is nothing left to fall back upon but hypothesis.

The behavior in different countries varies a great deal and this is yet another of the riddles with which the study is beset. At the same time, such differences should be of the greatest interest and open out a wide field for investigation, and appear to afford a series of clues which will doubtless be taken advantage of by the workers in those places where the disease is most feared. In Java it has been recognized as causing appreciable loss, but is apparently controlled by the continued planting of sound seed; it is suggested that the disease was, in any case, less virulent than in the New World in these latter days, and this has been attributed by some to a quantum of resistance acquired naturally by the cane plants long growing with the disease in their midst. Similar suggestions have been made by others regarding San Domingo and Cuba to be mentioned below. The Hawaii work, though doubtless very interesting, is not available; but it is indicated that, in fully infected fields (100 per cent), the loss is from 5 per cent to 40 per cent, according to the variety grown, and that this loss is in the form of deficient tonnage rather than diminished growth of poorer juice. In the early stages mottled plants grow well and their juices appear to be equally rich in sugar with healthy ones, but the stalks are always considerably lighter and presumably have less juice in them. In Porto Rico, four years' severe infection has made it

possible to advance more detailed figures than in continental United States. Stevenson estimates that, up to July, 1919, some $3,500,000 had been lost to the industry through mottling, and it is quite certain that the damage since then has been very serious. No statement can very well be made in Louisiana, for the disease was only definitely declared to be present in the same month (July, 1919), but, from such evidence as has been collected during the very detailed survey which has been concluded, it is thought probable that considerable losses have been experienced during the last few years. In San Domingo the disease is reported by Stevenson as widely spread, but not assuming the severe form of the Porto Rico epidemic; no case of stem infection has been met with by that observer and he hazards the suggestion that the virgin soils of the cane plantations may have something to do with this. This has also been urged with reference to Cuba, and certainly the disease acts there in a totally different manner from Porto Rico and the United States generally. There seems, in fact, to be little or no secondary infection and the disease has difficulty enough to hold its own with the reproduction by diseased sets. It is, as will be gathered from the former remarks by Grey, regarded with equanimity. In Argentina, on the other hand, yet another case is presented. Here too the disease is not regarded as dangerous, but this is traced to the fact that the canes growing, although fully infected, are almost entirely of varieties which, everywhere and even in Porto Rico, have shown a very high state of resistance to Mosaic, the older varieties having been discarded in this sub-tropical region in favor of Java seedlings with North Indian blood in them.

A natural means of fighting the disease is of course the introduction of immune varieties, the final refuge of all who have failed in their attacks on plant diseases. But, unfortunately, the only varieties which have hitherto been shown to be immune are such as cannot be commended for growing in tropical cane fields. Such are the Kavangire, determined by Cross to be identical with Uba, Cayana 10 used for syrup in the United States, and other so-called "Japanese" canes wherever found; typically thin, fibrous, freely tillering canes, possibly all of the great Pansahi group of Indian canes. Besides these there is the possibility of some new seedlings being found which are immune, but at present more than 1000 kinds have been shown to be susceptible, including all the well-known canes of commercial value and multitudes of seedlings; and, considering the parentage of the latter, it seems at least improbable that they will be found to differ from their parents in this matter of immunity. But we must here distinguish between immunity and resistance, two very different things. The Java seedlings referred to above are not in the least immune and take the disease with the greatest ease, and it is possible that they have introduced Mosaic into the new world; but its effect on them, although varying, is very slight, and perfectly good yields can be obtained from 100 per cent infected fields. The suggestion that this resistance is due to long experience of the disease in Java has already been referred to; but it seems to us to be much more likely that they owe this favorable character to their parentage, which is half North Indian, although in a different group to that of Kavangire. The Saretha group, to which their male parent belongs, is a much hardier one in India than the Pansahi. There is hope,

however, in this matter of resistance, for the thick canes vary greatly in it: quite a number are mentioned in the various papers referred to as more resistant than the rest, and trials have commenced with these both in Porto Rico and the United States. Thus, G.C. 888 and G.C. 1313, D 1135, D 117, B 6540 and L 511 are said to be worth multiplying for this reason, and L 1646, L 1606, L 1674 and L 1797 even show signs of possibly being immune.

One of the most interesting features in the case, which has only recently received attention, is that the particular virus attached to Mosaic in the sugar cane is capable of producing a similar disease in various other members of the grass family. This point has as yet by no manner of means been fully worked out, but Mosaic occurs, according to Brandes, in maize, rice, "millet," sorghum, "Panicum," foxtail, and crab-grass. The disease is said to attack these plants with difficulty even under favorable conditions; but, while it is likely that all of these plants can be infected directly from sugar cane, this has only been proved in the case of the last four. These became heavily infected when grown in the same greenhouse as diseased sugar canes while plants growing all around outside remained without a sign of Mosaic. The importance of this aspect of the matter cannot be overrated. It is sometimes assumed that the disease was originally one of some wild grass which handed it over to the sugar cane, and this idea receives some support from the peculiar mode of extension in Porto Rico, where it was at first chiefly met with in the hilly tracts. However this may be, the possibility of the wild grasses bordering cane fields acting as carriers is alarming enough for a detailed search to be made on plantations for any signs of the disease in the wild flora as well as in adjoining crops.

The control of Mosaic disease, as in sereh and many other diseases, outstripped our scientific knowledge of its character, and is planned upon a recognition of a couple of clear-cut factors. Diseased plants will always transmit the disease through cuttings taken from them, and secondary infection always takes place when susceptible varieties are planted near those affected. When the characters of the disease are universally known to planters and they can readily distinguish Mosaic plants from those with leaves otherwise marked, it should be easy rigidly to abstain from taking sets from diseased plants. In one case we can go further, for Egerton has shown that, in L 511, we can at once distinguish diseased canes after they have been cut, that is at the mill: diseased canes in this variety are stated always to have red stripes and these are entirely absent in healthy plants. But, ordinarily, one must depend on the blotching of the leaves and therefore make the selection for planting before cutting the canes. It would, moreover, be much the wiser course to secure healthy seed from fields in which no Mosaic occurs, for there appears to be an incubation stage of two or three weeks, during which infected plants may show no trace of the disease in their leaves, although the virus has already been introduced into their systems. It is a fundamental plank in all measures at present suggested for the control of the disease, that every diseased plant will pass on its virus in its cuttings and that no healthy plant can do so. But this is only half the battle. A few diseased plants, in an otherwise healthy field, will rapidly infect the whole field once the leaves are out, for we gather that this secondary infection takes place only through the

leaves. Therefore a system of "roguing" is necessary, and it is important that this operation should be carried out as soon as the first trace of the disease declares itself, namely when the plants are quite young. It is moreover necessary to dig out the whole stool, so as to destroy all the buds which otherwise may later shoot out their leaves to carry on the infection. These dug out stools need not be burned or otherwise destroyed, for it will be sufficient merely to throw them into the middles between the rows. This sounds very extraordinary practice in a highly infectious disease, but it has been shown that wilted plants are not to be feared: we presume because the suspected insect carriers will not find any juice in their tissues and will confine their attention to the more succulent growing plants in the rows. This main factor of insect carriers has constantly to be borne in mind, and the roguing should therefore be done before they enter the field of young canes, or are present in large numbers.

An eradication campaign has been started in Porto Rico, and Earle has given the results of the first year's work in the words of those planters who have adopted his suggestions. The work was admittedly carried out with varying thoroughness, and the results obtained agree closely with this. The cost in cases of slight infection appears to have been very moderate, often under a dollar per acre, but, in cases where 30-50 per cent of the plants in the field were affected through the planting of diseased sets, it naturally was a great deal more. At first it was not intended that eradication should be attempted in such cases, but the results of the first year's work have proved so eminently satisfactory, that it is now suggested that it might be attempted in all fields, and that even such as have 100 per cent of diseased plants need not be excluded. In these cases, however, nothing can be done in the absence of a ready source of healthy seed cane, and this is of course difficult to introduce. If this source is available the infected canes should be crushed without any attempt at using them for seed purposes. Where the sound seed is insufficient to plant up the whole area of healthy fields these should be kept as far as possible from the diseased plots, and increased rapidly for seed purposes. Ratooning should be totally dicontinued in fields suffering heavily from Mosaic.

The second line of control is the introduction of immune and resistant or tolerant varieties. Unfortunately, as already stated, the only ones at present known to be immune are those of the Uba or Kavangire class, and it is for the planters to decide whether these canes are worth growing for sugar making. They are definitely inferior to the tropical canes in certain particulars and are not therefore to be recommended for general use in the tropical belt where thick canes can be grown. With regard to resistance, there is a better prospect of success. A good deal of work has already been done on the subject. We know, for instance, that all of the Java seedlings which have North Indian blood in them are highly resistant. Although readily taking the infection, the presence of Mosaic has little influence on the greenness of the leaves: the growth is good and the tonnage heavy, while the juice does not appear to suffer at all. Here again it is for the planter to decide whether they are sufficiently rich in sugar to be introduced on a large scale in place of the former more tropical varieties which have been so badly hit by the disease. But there are, among the latter

class, great differences in their degree of resistance, as has been shown by Earle in another paper. Some of these have already been mentioned, and it is desirable that this work of selection should be strenuously pushed forward, and such as have responded favorably multiplied as rapidly as possible.

These appear to be the main facts of the case regarding Mosaic at the present moment. With the amount of energy being thrown into its study, it is certain that new facts will be brought to light, and the views expressed in this article will suffer change in various particulars. But, supposing that there is no alteration in the main facts of the case, there seems to be a probability that Mosaic will be mastered in place after place, and will again take its position among the minor diseases of the cane, many of which have, in their turn, assumed alarming proportions for a time. One fact is obvious: if the industry is to be carried on successfully and such visitations are not, every now and then, to catch the planters unawares, a greatly increased attention will have to be paid to the fields in the future. It is of little use to devote exclusive attention to the factory if the source of supply is liable at any moment to be cut off.

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[L. O. K.]

The Mottling Disease of Cane and the Sugar Production of Porto Rico.*

By C. A. FIGUEROA.

Since the year 1915 the cane growers of Porto Rico have been complaining that the sugar production of the Island has been diminishing with every suc-

* Journ. Dept. Agr. Porto Rico, 3:35-39, 1920.

"The disease reduces the tonnage and therefore also reduces the production of sugar per acre." This statement was made by the director of the Insular Experiment Station in his Circular No. 14, and to back up his utterance he mentions the following experiences:

A Java experiment gave these results:

Healthy cane, 21.23 tons per acre, first crop.
Mottled cane, 18.20 tons per acre, first crop.

RESULTS OF A HAWAIIAN EXPERIMENT.

	Tonnage of 3 Rows 80 Feet Long	Estimated Tonnage per Acre	No. of Canes	Average Weight per Cane (Lbs.)	Tons of Sugar per Acre
Healthy cane	2.786	101.13	835	9.27	14.98
Mottled cane	1.5495	56.24	623	8.01	8.43

Other Conditions Affecting the Sugar Production.

This work will not be complete if it does not contain a brief discussion of all factors that may have had some influence on the sugar production. The writer does not pretend to assume that every pound of sugar lost has been due to this disease. Though he firmly believes that the bulk of the loss is the result of the *matizado,* there are other causes to be taken into consideration.

Rainfall.

The rainfall records available are not complete and for this reason they do not appear in this work. However, it is a well-known fact that the severe drouths that have occurred in different sections of the Island, particularly in the south coast and in the Arecibo-Aguadilla section, have contributed to lower production. Furthermore, the scanty amount of rainfall in certain sections like the eastern coast have come just at the wrong time.

But even so, it is not reasonable to blame the lack of rainfall for the whole trouble. The precipitation records that are complete show that there is no uniform relation between production and rainfall.

Manures.

The following table [1] shows the importation of commercial manures by the district of Porto Rico during the last three years:

Year.	Tons.	Value.
1915-16	39,702	$1,735,391
1916-17	45,769	2,827,796
1917-18	40,811	2,929,726

This table shows that in the year 1917-18 the imports were cut down by 5000 tons. It also shows that the cost of commercial manures has gone beyond the reach of the small cane grower.

[1] Customs House records.

But if the small planter has not used as much commercial manure as before the war, he has used more stable manure, guano, etc. Moreover, the manure-mixing plants of the Island have increased their capacity to a considerable extent, and consequently lots of manurial ingredients have been imported. It is very probable that all of these ingredients have not been imported under the head "Manures" or "Fertilizers," but as "Chemical Products." The enormous increase of importations under this heading appears to confirm this belief.

On the other hand, these 5000 tons that were not imported last year are largely potash. All commercial manure users have missed this ingredient in their manures. This has led them to believe that lack of potash is to be blamed for the deficit in the sugar production.

However, manurial experiments on record in Porto Rico as far back as 1910 have failed to show the economic advantage of the use of potash as a fertilizer in cane cultivation. Professor Earle says in connection with the use of potash:

"Potash should not be taken into consideration, for its need is not so essential. Experiments with cane in Porto Rico show that the use of potash in these soils is of no such a great need. The demand for potash as a manure is one of the things 'Made in Germany.' Its use has been extended by means of the active propaganda of the 'German Kali Works.' For a good many years previous to the war this firm has been paying specialists in almost every agricultural country, whose business it was to work in favor of the potash." (Circ. No. 17, Ins. Exp. Sta., Recomendaciones sobre el Cultivo de la Caña en Puerto Rico.)

Tillage and Cultivation.

All those interested in agriculture in Porto Rico agree in that our methods of tillage and cultivation are rapidly and constantly improving. A trip through the cane section will convince anybody of this fact. Soils are better prepared; more attention is paid to manurial and cultivation problems; seed selection is beginning to be popular; the sight of implements such as the tractor, the harrow, the disc plow and others is familiar nowadays; and, in short, the sugar men are beginning to realize that sugar cannot be made in the factories if proper attention is not paid to the agricultural end of the sugar business.

Comparing the acreage with production for the last three years we have—[1]

Year	Cane Acreage (Cuerdas)	Total Sugar Output (Tons)	Tons of Sugar per Acre	Per Cent Decrease
1917	205,106	503,081.18	2.41	....
1918	256,431	453,975.55	1.77	9.7
1919	238,901	406,000.00	1.70	19.0

[1] From Bureau of Property Taxes and Report of the Treasurer.

This means that, taking the crop of 1917 as a basis for calculation, Porto Rico has lost 146,186.81 tons of sugar in two years. This is about equal to 30 per cent of its normal production for one season. The figure is large enough to command some attention.

[L. O. K.]

Infection and Nature of the Yellow Stripe Disease of Cane (Mosaic, Mottling, Etc.).*

By J. Matz.

Introduction.

In December, 1918, the writer began studies of this disease in Porto Rico. The following is a summary of experiments and histological studies made during a period of twelve months. Owing to the conflicting views among investigators regarding the nature of this disease there could not be obtained much guidance as to any one definite line of investigation to follow out, so that even previous experiments carried out by others had to be repeated in order to gain a clear path for any line of investigation.

In reviewing the literature on this disease it was found that although the disease has been recorded to have appeared in cane fields which were previously known to be free from any visible signs of it, yet there is hardly any records of exact observations of its transmissibility to known healthy plants. There is no doubt that a large part of the spread of the disease is due to the use of infected seed, but it is also an undeniable fact that new or secondary infections occur. This is supported by records of observations made in Porto Rico, Java, Hawaii and Cuba. It would be erroneous to assume that healthy cane showing new cases of yellow striping had in actuality the disease in such a dormant state as not to show its symptoms up to a period of several months or more. Tests as to dormancy were made, at the beginning of this work here, with seed pieces from cane which were in a not advanced stage of the disease. Portions of these canes were cut into pieces having one or two eyes each and placed in glass moist chambers for germination. The cane and glass chambers were sterilized to remove molds and bacteria. In forty-five trials, using cane from three different sources, not a single case was found where the symptoms of the disease were not observable in the unfolding leaves in the shoots of diseased seed. Diseased seed always produced diseased plants; in other words, if the disease is present in the cane it will show up at an early stage in the leaves, by its characteristic symptoms. Further tests along this line were made by planting diseased seed pieces in sterilized and unsterilized soil, in pots. Here the results were the same only with a slightly higher accentuation of the symptoms in unsterilized soil due to the fact that the seed piece breaks down quicker by the aid of ferments and fungi which sometimes abound in such soils, thus aiding in the stunting and deterioration of the young buds. In the unsterilized soil the young shoots became, in addition to the yellow striping, speckled with a reddish tinge, and formed a shorter stem with the leaflets growing in more or less of whorls.

There is the possibility of the symptoms being so faint as to evade detection to the casual observer. The various symptoms of the disease on different varie-

* Jour. Dept. Agr. Porto Rico, 3:65-82, 1920.

ties of cane have been described in previous publications, and it is plain that the disease can be recognized in all instances. However, the writer had under observation four plants in pots which showed only an occasional thin stripe of a darker green on a field of lighter green. These plants were kept up in good condition, having applied to them a liberal amount of nitrate with frequent watering. The symptoms of yellow stripe always existed in these plants in the older canes, but in a rather less pronounced form. The young shoots, however, which occasionally come up at the bases of these canes show the symptoms more distinctly. Other plants, diseased, and growing under the same condition close to the above show the disease very clearly and distinctly. On the other hand, the same variety, Crystalina, is known to produce clearly distinct symptoms upon its becoming diseased in the field. The above four plants are kept for further observations. A degree of severity exists in the different fields and in individual cane plants. The severity of the disease depends, as has already been observed by others, on varietal resistance, length of time the disease is propagated in a given plant, and local conditions under which the cane is growing. In an infection experiment conducted in the greenhouse of the Insular Experiment Station, mention of which was made in last year's report, the "canker" stage was observed to have occurred in a cane in three months from the time when the first signs of the disease were noticed. This is contrary to views held by others, i. e., that it takes a certain number of generations for the canker stage to arise. It was really the general unfavorable conditions for the growth of the plant, as it was grown for almost a year in a five-gallon tin can, that helped the canker stage to be shown up sooner.

INFECTION EXPERIMENTS.

I. *Contact.*

During the first part of this year experiments such as have been tried by others have been repeated in order to gain an intimate knowledge of the behavior of the disease. Healthy and diseased plants were planted together in the same pots; healthy and diseased seed pieces were split in half, and then a diseased half and a healthy half were fastened together and planted. There were no transmissions of the disease to the healthy plants. The healthy plant, though in contact with the diseased plant, has not contracted the disease. The healthy seed produced healthy shoots right alongside the diseased seed and shoots in the same pot. Healthy seed pieces were watered with water in which diseased cane was allowed to stay for some time. No infection occurred.

An experiment was made to find out if the disease could be transmitted through the roots. Diseased tissue was fastened onto the root eyes of healthy seed, so that the growing rootlet may come in contact with the cut surface of the diseased tissue. Eight of the healthy seed pieces germinated and the shoots were healthy. After four months in the pots two shoots of the healthy seed showed symptoms of yellow stripe. The experiment was repeated but gave negative results. The fact that the symptoms were belated in showing up would indicate that the two plants became infected through another source. There were diseased cane in the greenhouse.

Another experiment was made in the following manner: Healthy and diseased seed pieces were cut to contain three dormant buds each. The middle buds were carefully cut out with a sharp knife. Care was taken to make the cut at least one-half inch on all sides from the bud, in order to leave uninjured root eyes and some tissue for the growth of the bud. The buds from the healthy seed were then inserted in the diseased seed in the places of diseased buds and the buds of the diseased seed were inserted in the healthy seed. Practically all of the buds germinated and from the first no transfer of the disease was observed to have taken place either in the healthy seed with the diseased buds or in the healthy buds inserted in the diseased seed. The grafts thus made did not live long, but the seed in which they were inserted developed sound shoots from their original two remaining buds. It was thought that by bringing in contact the cut ends of the vascular systems of diseased and healthy cane a transmission of the disease might take place. But no infection occurred in this experiment.

II. *Juice.*

Experiment 1.—On April 16, an experiment was made in the following manner: Five cane plants of about 8 months old, growing in five-gallon tin cans in the greenhouse of the Insular Experiment Station were examined and found free from any symptoms of yellow-stripe disease. Each of these plants consisted of one single stalk of about one inch in diameter and averaging about three feet in height. At the bases of each were one or more shoots of about six inches in height. These shoots also were free from yellow-stripe disease symptoms. The five stalks were cut back leaving stumps of about four inches above ground, the shoots were left as they were. Juice from a yellow-striped piece of cane was pressed out and injected, with a hypodermic needle, into the stumps near the surface of the ground. On April 28 typical symptoms of yellow stripe was observed in the lower parts and along the midribs of the central leaves of two shoots in two out of the five pots. At first only a few, larger, light green, narrow areas were noticed; later these light green areas spread all over the leaves and they became patterned with short alternating light-green and green stripes. In one of the two pots which showed infection on the 28th of April there were two shoots at the base of the old stalk but only one shoot showed infection on that date; however, about a week later the other shoot became infected. In three months the infected stalks have become more or less shrunken at the internodes and showed typical cases of the "canker" stage. The other three plants remained free from the disease throughout the experiment, which lasted ten months. In this and later experiments the positions of the plants were noted and they were kept in the original places throughout.

THE POSITION OF PLANTS IN EXPERIMENT 1.

	Plants inoculated April 16				
	No. 1	No. 2	No. 3	No. 4	No. 5
April 28 ...	free	diseased	free	diseased	free

Experiment 2.—On May 1 a similar experiment was made in the same greenhouse with similar plants. Twenty plants were inoculated with juice from diseased cane and 20 were left uninoculated as checks. On May 14 two of the inoculated plants showed the symptoms of the yellow stripe disease. These plants are marked "D" in the next table.

The positions of the pots in this experiment were thus:

Bench 1:										
Inoculated	1	2	3	4	5	6	7	8	9	10D
Check	1	2	3	4	5	6	7	8	9	10
Bench 2.										
Inoculated	1	2	3	4D	5	6	7	8	9	10
Check	1	2	3	4	5	6	7	8	9	10

Experiment 3.—On the same date as the last experiment 10 plants were cut back only a little above the growing point; 5 of these were inoculated in the cut surface of the top by injecting diseased juice with a hypodermic needle, and 5 were left as checks. All of these have remained free from the disease.

Experiment 4.—On May 2, 25 healthy stools about three months old were transplanted from the field to the greenhouse in pots. The plants were cut back as in the first two experiments, and 8 of these were inoculated with diseased juice and tissue; that is, in addition to the injection of juice, pieces of diseased cane were forced into small holes in the stems. All 25 plants remained free up to October, when one of the checks developed the yellow-stripe disease symptoms. It must be stated that the four plants which developed the disease in the first experiments were of a lot of cane which were more mature than the last 25 plants. In order to test this point 18 seed pieces of mature Crystalina cane were cut to one or two eyes, 12 of these were inoculated near the base of the bud, by boring a hole into the seed piece three-quarters inch deep and directly into it was pressed juice from diseased cane, and 6 were inoculated in the same way with healthy cane juice. All were planted in pots and placed in the greenhouse.

Experiment 6.—At the same time 35 Crystalina stools in a field that has just been cut were inoculated with juice in the stubble near the bases of sprouting buds. In both of these last two experiments not a single positive case developed. The plants in the pots were transplanted, after four months in the greenhouse, to an open field, and up to the present no signs of the disease have become visible.

Natural and Secondary Infection.

Experiment 7.—During the time when the above experiments were made there has not come to the writer's notice a case of secondary infection in the greenhouse, nor were there any such cases reported previously. This was rather strange, as secondary infections were being picked up every two or three weeks in the adjacent cane fields. The greenhouse was not "insect proof." In order to make sure that secondary infections do occur in known healthy cane, 48 seed pieces from three healthy and mature Crystalina canes were planted in pots and placed in the greenhouse. After two months from germination three of the 48

showed symptoms of yellow-stripe disease. However, these three plants, together with a number of others of the same lot, were on the ground instead of on a bench.

Experiment 8.—So another series of 50 seed of three healthy white Otaheita cane were planted in pots and all were placed on clean benches. In about three months from germination one of two shoots from two separate seed pieces in the same pot became distinctly diseased.

Experiment 9.—Ten cane stools having been cut back and transplanted from the field to pots in the greenhouse have been allowed to grow for four months. These showed no signs of yellow-stripe disease during that period. At the end of four months they were cut back and allowed to sprout again. One shoot began to show yellow-stripe disease in the unfolding leaves, and in two weeks the entire stool became diseased.

Experiment 10.—On May 15 five healthy stools in five pots were inoculated with diseased juice in the stalks near the root crowns. Up to September no symptoms of yellow-stripe disease have developed. During the first part of September the plants were all cut back and allowed to sprout up again, and two plants began to show the yellow-stripe disease in the central unfolding leaves of their shoots. It is assumed that these were secondary infections. It is of interest to note the development of the disease in one of these pots.

The position of the row of pots on the bench was thus: 1 2 3 4 5.

Numbers 2 and 5 became diseased. No. 5 had two small *cepas* of 5 to 7 shoots. Both *cepas* came out from two original buds on the sides of a single seed piece. At first one *cepa* showed the disease, the symptoms of yellow stripe appearing first in one shoot and then in another until all became visibly infected. In about three weeks the second *cepa* became diseased, and again a gradual spread of the disease from one shoot to another was observed. In all of these shoots the central leaves always showed the symptoms first. It appears that the disease gradually communicates from one shoot to another through a common channel.

It is quite certain from observations made on healthy and diseased plants grown in close contact with one another, that mere surface contact does not transfer the disease to healthy plants. In the greenhouse a row of 10 diseased plants were placed alongside of a row of 10 healthy plants, allowing for contact between the healthy and diseased leaves, and not a single case of new infection resulted. However, during the late part of the summer a healthy plant which was adjacent to a diseased one in the greenhouse became diseased. This is the first case of its kind in the greenhouse; its occurrence should rather be layed to an outside agent rather than to its being close to a diseased plant.

The occurrence of yellow stripe in the greenhouse has been in all features similar to the way it works in the field. It attacks the young shoots and it is sporadic in location; it picks out a plant here and there only, and there is not a general spread taking in complete areas. In the field a new infection may sometimes be observed on large cane, but from personal and close watch of the plants

in the greenhouse secondary infection on more or less grown cane has not been seen.

The following conclusions can be drawn from the above observations: first, that healthy cane from healthy seed became infected with the yellow-stripe disease; and secondly, that the disease has been transferred artificially to healthy plants in four cases at least. It should be observed that in both, Nos. 1 and 2 experiments, the disease showed up in about two weeks from inoculation and there were no other new infections in the other plants in the greenhouse at that time. However, the exact method to insure takes is not known as yet. The prevailing idea that insects are the carriers of this disease is highly plausible, but the writer has not taken up this phase of the problem.

Histological Studies.

Histological studies of yellow-striped cane were made with the view to determine if possible in what way the disease affects the tissue of the host. A search for abnormalities in the interior of the cane stalk and leaves of diseased plants was made. Tissue from diseased mature cane stalks, from underground parts, from growing points and from leaves were cut with a sharp razor free hand and with the microtome. In studying microscopic sections of the outer cankered tissues of yellow-striped cane it was noticed that sometimes the parenchyma as well as collenchyma cells of the discolored areas possess very distinct, single, spherical, darkly colored and dense protoplasmic bodies. At first glance these resemble spore bodies of some organism. (Fig. 1 *a, b.*) These bodies were also

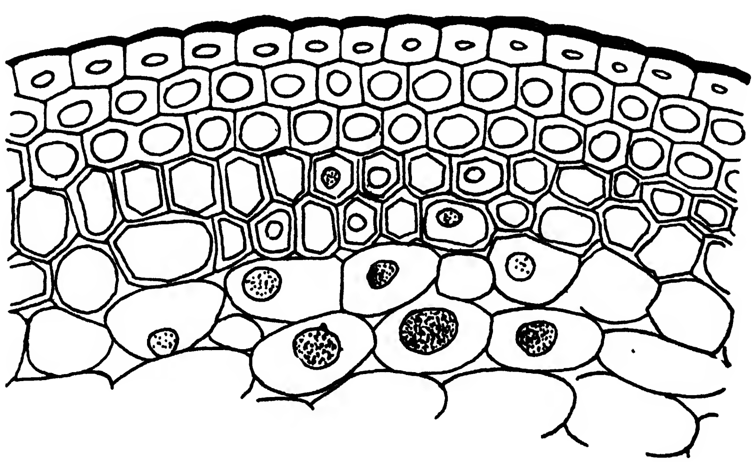


Fig. 1a. Dense and deeply-colored nuclei in cane tissue near the rind. Drawing of a free-hand section from a yellow-stripe diseased stalk. (× 150.)

found in the center of diseased cane. In searching in the tissues of non-yellow striped cane it was found that these bodies also exist in parenchyma cells there. It was found in the base of a young stalk which was injured by a mechanical agent, it was found in the cells of roots of non-yellow striped cane and in the injured part of a stalk of cane of the same nature. It seems clear enough that under certain conditions of growth the nuclei of certain cells become dense

and deeply colored and give the appearance of dense granulation when influenced by an inhibitory or injurious factor. Sections of tissue containing the spherical bodies referred to above could not be permanently mounted in the usual way as alcohol dissolves those bodies. When placing a free hand section in alcohol the spherical bodies become vacuolated and ultimately disappear from view, only a very thin wall being left.

Paraffin sections of the uppermost nodes of yellow-striped and healthy cane were made. It was observed that a difference in the appearance of their respec-

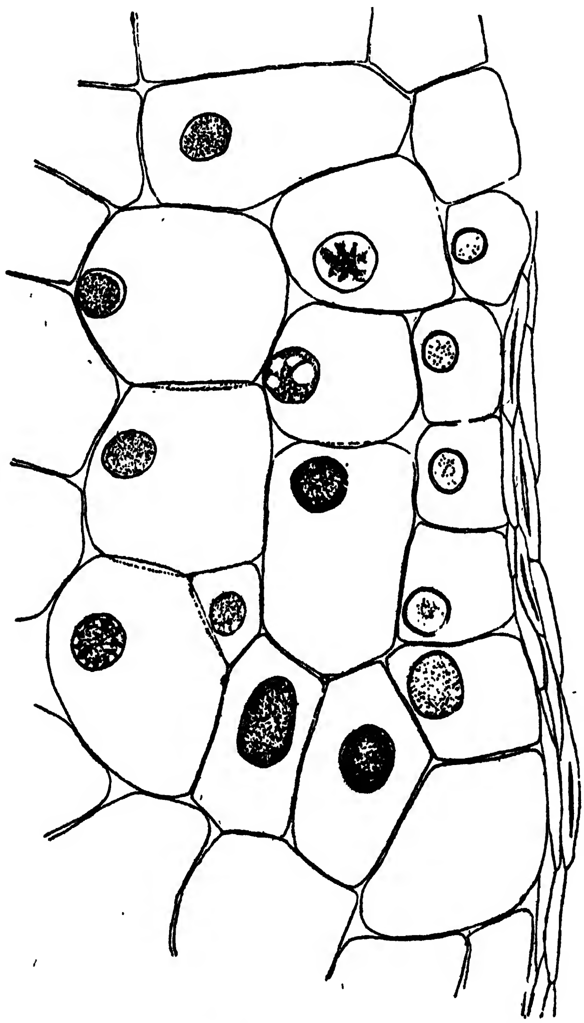


Fig. 1b. Drawing of similar bodies as in Fig. 1a, in cells of non-yellow-stripe but otherwise injured cane tissue. (× 250.)

tive tissues existed (Figs. 2, 3, and 4). In the diseased tissues some of the parenchyma cells between the fibro-vascular bundles were filled with a protoplasm which was dense and finely granulated, ~~the~~ bundles showed apparently the same substance in the sieve tubes and vessels,[1] while in the cells of the healthy

[1] The writer has of late seen specimens of cane affected with gum disease due to *Bacterium vascularum*. This disease is distinctly different from the yellow-stripe disease, the gum of the former is yellow and full of bacteria which are easily cultured. No slimy exudation occurs in yellow-stripe disease.

cane the fibro-vascular bundles were free and the parenchyma between the bundles contained scattered and coarser granules. The last named are common in cut and exposed portions of young growing parts of cane.

Leaves of about the same age of healthy and yellow-stripe cane were studied. Figures 5 and 6 show a striking difference in the appearance of the two. The healthy leaf in cross section shows no abnormality except slight shrinkage; in the diseased leaf some of the epidermal cells, especially near the stomata, and some internal cells show dense contents which is colored slightly brown, and which is similar in appearance to the abnormalities found in the cells of the cane stem. It seems that a foreign plasmodium-like substance is apparently present in the cells of the yellow-striped cane leaf and stem tissue.

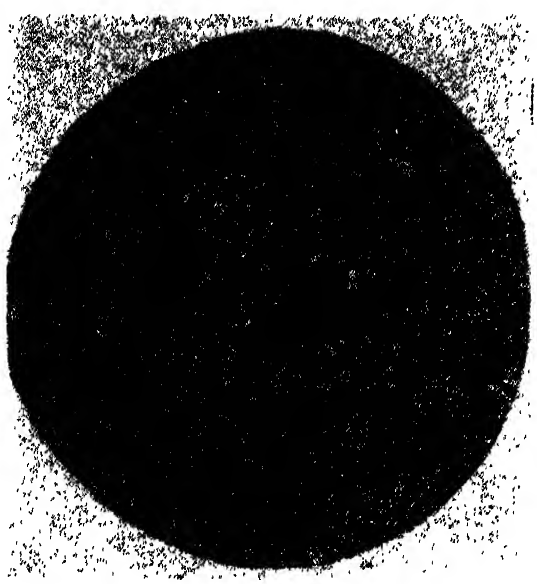


Fig. 2. Photograph of a vascular bundle from near the growing point of yellow-stripe diseased cane, showing the finely granular substance in the vessels. (× 50.)

Further research along this line revealed the presence of the above plasmic substance more constantly and in a more defined form in "cankered" cane stalks. In investigating the histology of "cankered" cane a feature, which has not been mentioned before in the literature on the subject, has been noticed. Cankers have been characterized as exterior symptoms consisting of a few outer layers of deteriorated cells, but in reality one may find separate and distinct pockets of brown to reddish-brown tissue deep in the interior throughout cankered cane. More often such a discolored region may be found in the form of a short streak, several centimeters in length, usually very close to the rind of the stalk, but these streaks are not always exposed as they are found even where no breaking of the outermost layers of cells has taken place. Together with these distinctly brownish-colored areas there may also be present in the interior of stalks small

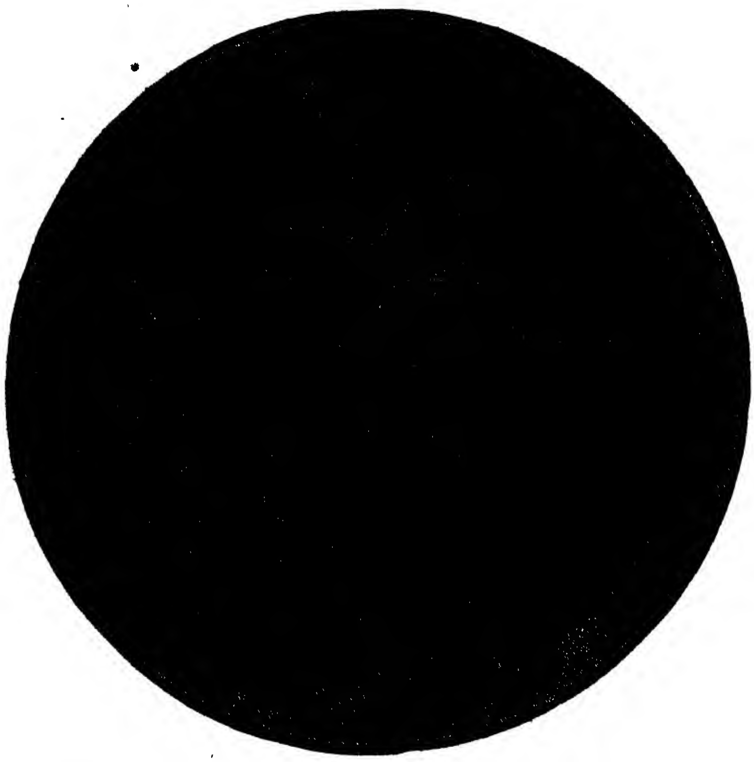


Fig. 3. Photograph of a cross-section through a growing point of yellow-stripe diseased cane. Note the character of the parenchyma cells and compare with Fig. 4.

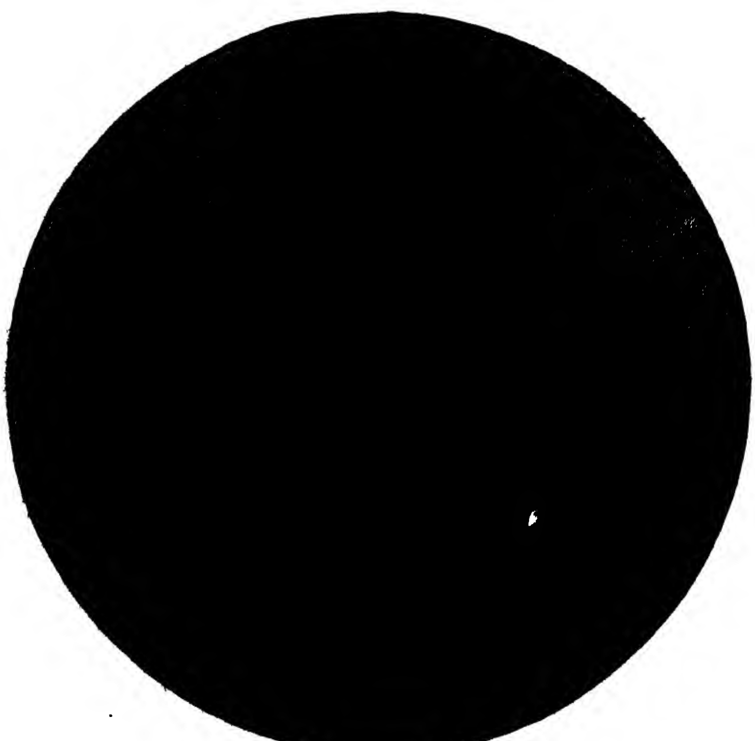
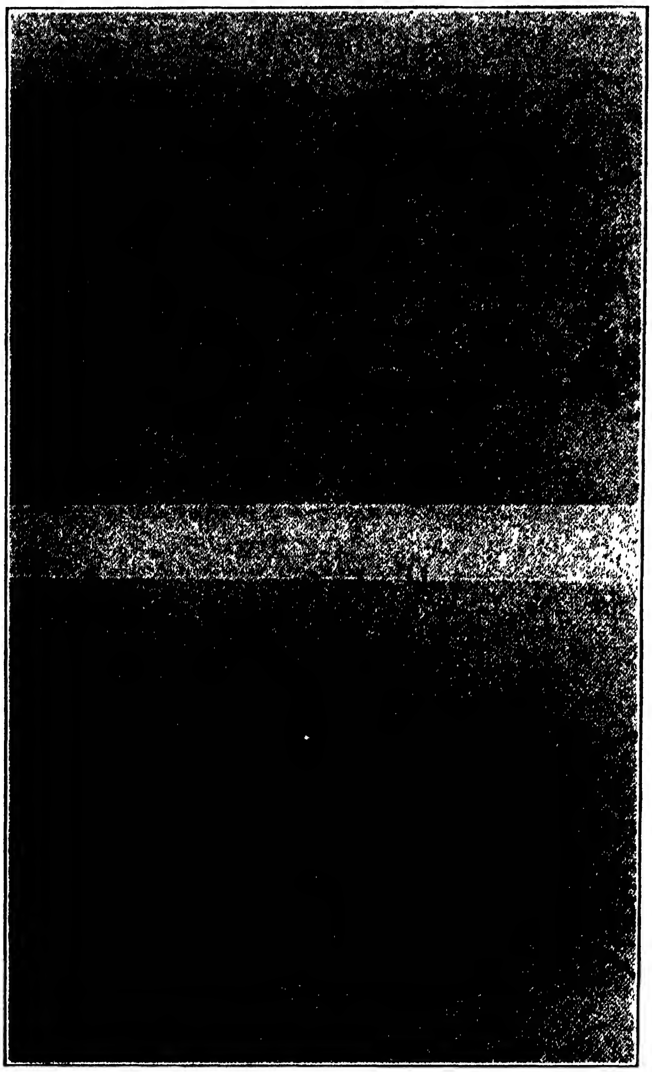


Fig. 4. Photograph of a cross-section through a growing point of a healthy cane stalk. (× 50.)

longitudinal and light-colored areas where the parenchyma cells have entirely collapsed and leaving an empty cavity of a millimeter or more in width and of variable length. Microscopic sections of the discolored areas in yellow-striped cane stalks show that some parenchyma cells are full of a more or less hardened or compact, densely but finely granulated, and slightly browned plasma. (Fig. 7.) Usually there are small groups of a few cells thus filled, but it is not uncommon to find only a single cell (Fig. 8) full of the granular material while the sur-



Figs. 5 and 6. Upper figure is a photograph of a cross-section through a yellow-stripe diseased cane leaf. The lower figure is a photograph of a cross-section through a healthy cane leaf. (× 100.)

rounding cells only show a slight brownish discoloration in their walls. This phenomenon is common in older portions of more or less full-grown cankered cane, especially where an alteration in color exists in the stem tissue. It has also been observed in leaf sheaths of yellow-stripe diseased cane. Here it is found in slightly depressed areas on the inner side of apparently uninjured leaf sheaths.

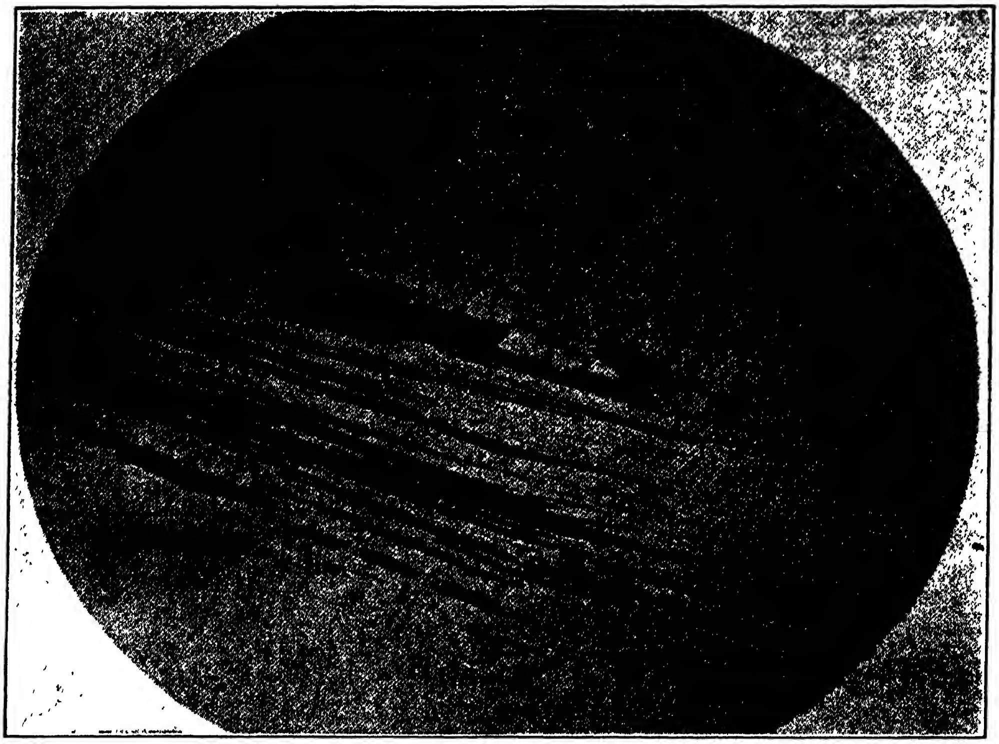


Fig. 7. Photograph of a longitudinal section through a node of yellow-stripe diseased and cankered cane, showing a group of plasma-filled cells at X. (× 50.)

Fig. 8. Photograph of a section through an interior canker of yellow-stripe diseased cane, showing in the center and near the lower left-hand corner single cells filled with finely-granular plasma. (× 250.)

It seems that the plugging of parenchyma cells in this manner is a diagnostic feature peculiar to yellow-stripe disease.

Free hand sections and sections from tissue which was fixed and killed and imbedded in paraffine, from internal portions of cankered cane, were treated in the usual way, *i. e.*, dehydrated with alcohol and cleared with xylol. The cells which contained the dense and finely-granulated substance did not lose it in the process of mounting.

In examining these sections with the microscope it is at once apparent that

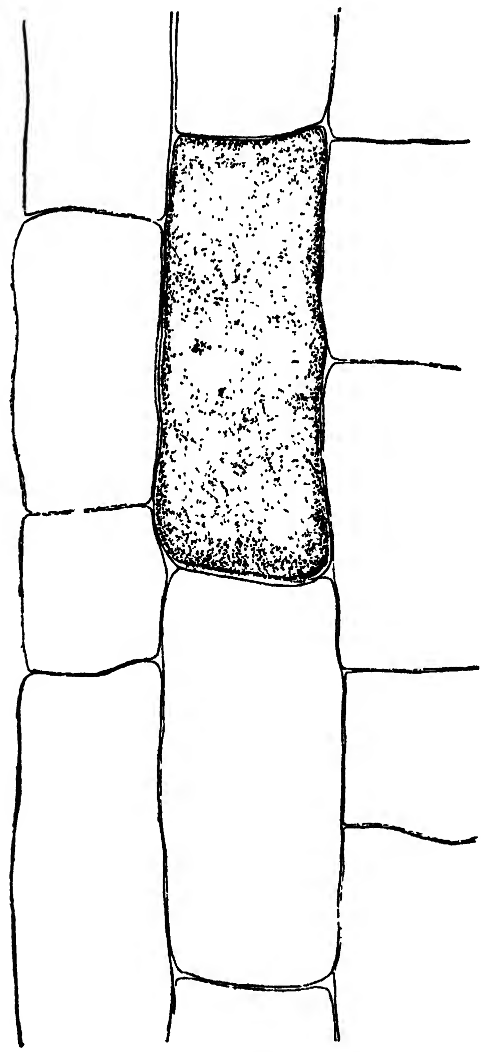


Fig. 9. Camera lucida drawing of a plasma-filled cell in an internally discolored area in yellow-stripe diseased cane stalk. (× 333.)

the granular substance is made up of a mass of small hyaline bodies more or less uniform in size. However, their exact size and form could not be ascertained, due to the fact that the whole mass is in the form of a compact plasma. The hyaline bodies which are dotted throughout the mass are less than one micron in length in sections from freshly cut cankered cane. They more nearly resemble nuclear granules in a mass of cytoplasm. They are less clearly defined than masses of bacteria.

Early attempts to induce growth development in agar from the above plasma-filled cells have failed. It was thought advisable to observe the condition of cankered cane in more than one stage. Therefore such cane was collected from three different parts of the Island,—south coast, north coast, and northeast sec-

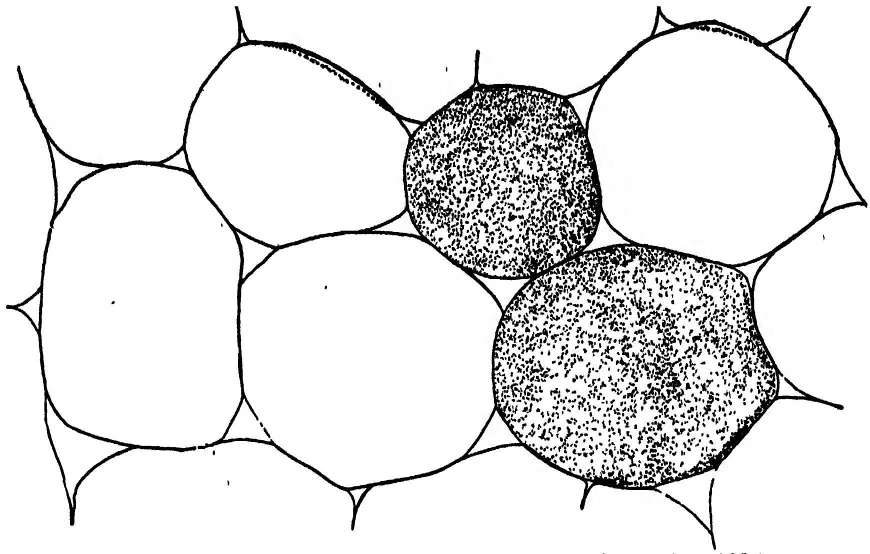


Fig. 10. Same as in Fig. 9, in cross-section. (× 333.)

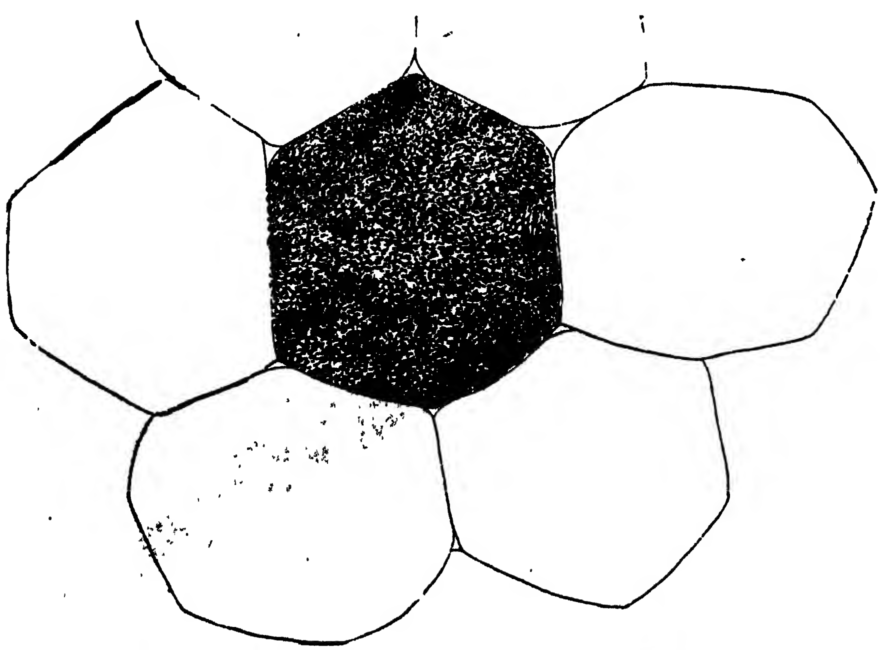


Fig. 11. Drawing of a section of yellow-stripe diseased cane tissue two months after the cane was cut. (× 400.)

tion. The local and scattered plasma-filled cells were found in the cane from the three parts mentioned and in the varieties Rayada, Cavengerie or red cane, and other kinds. In growing cane the condition of the plasma-filled cells were similar in all canes examined. Some of the cankered cane was kept in a covered chamber for two months, so that the cane became devitalized and yet not much

dried out. Free hand sections of this material showed the granular plasma material in the parenchyma cells in the same proportion as in freshly cut cane, but the granules in the former were more distinct, irregular in form, elongated and somewhat larger. In addition rotary movement of the individual minute bodies within the host cells was distinctly noticeable. It appeared that growth or a separation into more distinct individuals took place. It was very clear from the material at hand that the compact plasma in the cells of freshly cut cankered cane were in every way similar in appearance and distribution to the plasma in the cells which were seen in the more devitalized cane, only that in the latter more distinctness was observable. However, it was felt that sugar-cane treated in this manner is bound to become overrun with microorganisms and so more cankered cane was obtained, sterilized in bichloride of mercury and kept in the moist chamber for daily observation. It was found that in the course of two days some cankered cane showed a greater distinctness in the granulation of the characteristic plasma-filled cells, and that after eight days motility was observed in the plasma mass. As to the exact nature of this organism in the cankered cane cells nothing more definite can be said until more data are obtained in the process of investigation.

In cane otherwise diseased or injured by borers or fungi a reddish discoloration usually is found, but it is more or less continuous and is confined more to the vascular bundles. Such bundles often contain a homogenous gummy substance which is not at all like the substance in cankered cane parenchyma cells. Discoloration of parenchyma cells in non-yellow striped cane may also occur, but the discoloration is not of the same character as in yellow-stripe disease tissue. In cane diseased because of an invasion of fungi or other destructive agents the discoloration is more confined to the phloem and vessels and to the cell walls of parenchyma. A red phloem and gummed vessels are signs of wilt and decay due to fungi, bacteria, insects or mechanical injury. A continuous cavity in the pith or center of the stalk is a common effect of fungus invasion.

Further work is being done and planned with the view to clear up some of the phases of the problem of yellow-stripe disease.

From a study of the internal structure of cankered cane it is clear that actual deterioration and breaking down of cells in the interior of cane in an advanced stage of the yellow-stripe disease takes place. This effect is due to no other cause than to the destructive action of the infective substance of yellow-stripe disease, as there is apparently no connection between these interior sick cells and other outside mechanical or organized agencies. Furthermore, this substance, resembling a *Plasmodium*, in some of the interior cells was found to be constantly associated with yellow-striped cane in an advanced stage of disease.

[L. O. K.]

The Mosaic Disease of Sugar Cane Order, 1920.*

Order under Section 4 of the Protection from Disease (Plants) Law, 1915 *(Law* 3 *of* 1915).

Whereas it is provided by Section 4 of the Protection from Disease (Plants) Law, 1915 (Law 3 of 1915), that it shall be lawful for the Governor from time to time by Order to be published in the Jamaica Gazette to prescribe the measures to be taken for the treatment of any infectious plant disease by the owner, occupier or person having the charge or management of any land, whether the land shall or shall not have been declared to be infected or suspected of being infected with plant disease and generally to make provision for the purpose of preventing the introduction and spread of plant disease or of any particular plant disease named in any other Order;

And whereas the Mosaic Disease of Sugar Cane is a plant disease which the Governor in Privy Council has declared to be an infectious plant disease and notice of such declaration has been published in the Jamaica Gazette;

Now therefore, the Governor is pleased to order and prescribe as follows:

1. The Occupier or other person having the charge or management of any land on which there are Sugar cane plants infected with the Mosaic Disease of Sugar Cane, whether the land shall or shall not have been declared by order published in the Jamaica Gazette to be infected or suspected of being infected with plant disease, shall take the following measures for the treatment of the said Mosaic Disease of Sugar Cane:

(A) *In the case of diseased stools of Sugar Cane in plants and ratoon cane fields established before the* 15*th September,* 1920, *or within three months thereafter.*

(A) 1. If less than ten per cent of diseased stools are present in a young plant or ratoon cane field where the period of growth of the sugar canes has been less than four months, the affected stools shall be pulled out or dug completely and allowed to wither and die.

(A) 2. If the number of diseased stools amounts to or exceeds ten per cent in any cane field the treatment as prescribed in Rule 1 supra shall not be enforced.

(A) 3. If the canes affected with the disease are of four months' growth or more, Rule 1 supra shall not apply.

(A) 4. No cane tops or other seed-pieces from cane fields affected with disease to an extent in excess of ten per cent shall be removed from any such cane fields for the purposes of planting after the publication of this Order.

(B) *In the case of diseased stools of sugar cane in plant and ratoon cane fields which have been established after the* 15*th December,* 1920.

(B) 1. All diseased stools in young plants or ratoon fields of sugar cane of less than four months' growth shall be pulled out or dug out completely and left to wither up and die.

* This "Government Notice" is interesting in that it shows the methods by which they propose to control Yellow Stripe disease in Jamaica. It reached us in the form of a hand-bill.

Provided that in any case where the incidence of disease is in excess of one diseased stool per ten stools in any cane field the owner or occupier shall be entitled to appeal to the Director of Agriculture, who shall decide what treatment, if any, shall be carried out.

(B) 2. Rule A. 4. (supra) as to the removal of canetops or other seed pieces from infected fields shall continue to apply at all times during the existence of this Order.

DEFINITIONS.

In this Order the term "*Established*" shall be taken to mean that the oldest shoots of sugar cane in the field are not less than six inches in height.

"*Diseased stool*" means a stool of sugar cane with one or more diseased shoots or stalks arising either from a single seed-piece or from one root of a ratooning sugar cane. The age of a field of young plant-canes shall be reckoned from the time when the planting of the seed-pieces was completed.

The age of a field of young ratoon canes shall be reckoned from the date when the cutting of the previous crop was completed.

If these dates have not been recorded, the age of the plant or ratoon canes shall be determined by an Inspector of Plant Diseases.

2. This Order may be cited as "The Mosaic Disease of Sugar Cane Order, 1920."

3. The interpretation Law 1900 (Law 9 of 1900) applies for the purpose of the interpretation of this Order in like manner as it applies for the purpose of the interpretation of a Law.

L. PROBYN, Governor.

King's House,
Jamaica,
15th September, 1920.

2. His Excellency also directs the publication for general information, of the following description of the Disease:

Description of the Mosaic or Mottling Disease of Sugar Cane.

Cause:—The disease is due to an invisible virus (probably an ultramicroscopic organism) which infects the growing points of the shoots (probably carried by insects) so that all the leaves and all the joints and buds, developed thereafter, are infected. If such infected stalks are planted, the disease will always show in the young shoots (primary infection).

The virus can be carried through the air, from such diseased plants to the growing points of healthy plants (secondary infection).

There is no evidence yet that the disease is transmitted by the soil.

Symptoms:—To detect the disease, the young leaves in the hearts of shoots or stalks of any age should be examined. If pale green or yellowish green blotches or broken stripes are present on a normal dark green ground, or dark green blotches or stripes on a pale green or yellowish ground the disease may be concluded to be present. If the infection is primary (in the seed-pieces of plant cane or in the root-stock of ratoons) the leaves frequently show opaque white spots and stripes in addition to the other symptoms. In many varieties, the white markings on the leaves in primary infection are accompanied by white stripes on the joints. A diseased stool can usually be detected from a distance of twenty yards or more by its pale color.

The symptoms on the leaves should not be confused with pale spots due to fungus (which become brown or dead at the center) or numerous minute flecks, due to puncturing insects, nor with chlorosis or blanching, in which disease the pale stripes extend throughout the whole length of the leaves or the latter are entirely white.

[L. O. K.]

Mosaic Disease of Corn.[1]

By E. W. Brandes.[2]

Distribution

In connection with an investigation of the mosaic disease of sugar cane, a similar disease of corn has been observed by the writer on several occasions in widely separated regions.[3] On April 18, 1919, corn of an unknown variety was seen to be affected with typical mosaic symptoms in a field just west of Peñuelas, P. R. The percentage of affected plants was small, however, only 20 individuals being found in the field of some 5 acres. The corn averaged about 24 inches in height at this time and was planted between rows of sugar-cane stubble which had not been completely killed out in preparing the land for the corn. All the sugar cane was affected with mosaic. In July, 1919, corn of the White Creole variety was seen at the Sugar Experiment Station, New Orleans, La., in which the same condition was apparent. This corn was more than half grown, and the typical streaking of the leaves was somewhat obscured by certain leafspot diseases, among them the leafspot caused by *Physoderma zeae-maydis*, by which the corn was severely attacked. About 10 per cent of the plants in the field were affected with mosaic. In adjoining fields of sugar cane nearly 100 per cent of the plants were affected with the sugar-cane mosaic. In 1920 corn of the same variety was examined early in the season, and a much more serious infestation was found. The corn had been planted following sugar cane, and occasional diseased stools of the latter not killed by the plow were found all through the corn field. More than 30 per cent of the corn plants were affected. The cases were more abundant in the vicinity of the sugar-cane stools referred to above, but cases could be found many rods from any living cane. Of course, it is possible that a stool of cane had sprouted between the rows in such a situation and later had been killed by the cultivator. In May, 1920, identical cases of mosaic were seen in a field of corn near Cairo, Ga. As in the cases reported previously, a neighboring field of sugar cane was slightly infested with mosaic.

Diseases of corn bearing a decided resemblance to the one in question have been reported from other countries. Dr. H. L. Lyon states[4] that in the Hawaiian Islands a disease of corn which resembles sugar-cane mosaic is very serious. William H. Weston[5] describes a disease of corn in Guam which may be identical with the one under discussion. He mentions yellowing and dwarfing among the symptoms and states that the leaves exhibited mottling and striping.

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1 From Journal of Agricultural Research, 9:517-522, 1920.

2 Pathologist, Office of Sugar-Plant Investigations, Bureau of Plant Industry, United States Department of Agriculture.

3 Brandes, E. W., "The Mosaic Disease of Sugar Cane and Other Grasses," U. S. Dept. Agr. Bul. 829, 26 p., 5 fig., 1 col. pl. 1919.

4 In verbal communication, January, 1920.

5 Weston, W. H., "Report on the Plant Disease Situation in Guam," Guam Agr. Exp. Sta. Rpt. 1917, pp. 45-62. 1918.

Varietal Susceptibility

Just enough work has been done on varietal susceptibility to prove that all varieties of corn do not respond in the same way. The writer has never seen such excessive injury as that described for the unknown variety in Guam by Weston. In Louisiana the injury to corn of the White Creole variety, while marked in some individuals, was not excessive, excepting when the plants were infected early in the spring. The variety U. S. Select No. 182 is very susceptible to mosaic, but is not especially injured by it. Golden Bantam sweetcorn could not be infected in the greenhouse by methods which were successful with U. S. Select No. 182. Golden Bantam was planted unprotected in a greenhouse with hundreds of infected sugar-cane and sorghum plants. The corn aphis quickly migrated to the young corn plants from diseased sorghum in great numbers, but no cases appeared among the Golden Bantam seedlings. It seems probable that this variety is immune.

Importance

No figures are available on the amount of loss sustained on account of injury to corn. The writer is inclined to believe that in this country no great damage has been done thus far. Probably the disease was introduced on sugar cane within comparatively recent years, in which case it may become more important in the future. At present, however, our chief concern is with its relation to the sugar-cane crop. Corn is almost invariably used in the rotation on sugar-cane land, so that no plantation is ever without corn in some of its fields. This means, of course, that the possibility for spread of the disease is greatly increased. Overwintering by the virus has been demonstrated only in the vegetative portions of the sugar-cane plant, but the existence of other graminaceous hosts certainly complicates the problem of control.

Symptoms

In corn as in sugar cane the most conspicuous symptom of mosaic is the streaked and irregularly mottled appearance of the leaves. In corn, however, the lower, older leaves have a greater tendency to resume their normal color, so that it is sometimes difficult to demonstrate the mosaic patterns in such leaves. In the youngest leaves, either the normal dark green or the pallid, affected tissue may predominate in a given specimen, but the latter condition is most frequently met with. In such cases the areas which remain normal are in the shape of broken or interrupted streaks or lines extending in the general direction of the long axis of the leaf (Pl. 95), and the contrast in color between these areas and the surrounding pallid areas is very decided. The streaks vary greatly in size, ranging from mere points to elongated "islands" of dark green 2 or 3 cm. or more long and several millimeters wide. The margins of such streaks may be straight or undulating. In most cases the mosaic pattern is more prominent at the base of the leaf, where it diverges from the leaf sheath. Where the normal dark green is predominant, the light green, affected tissue appears usually as a

very fine mottling or as irregular elongated streaks on the darker background. From the foregoing description it can be seen that the patterns vary considerably, and yet they have certain general characteristics which make it almost impossible to confuse this condition with any other affecting the leaves.

Infected plants are always lighter in color than healthy plants. When viewed from a distance such plants can be picked out with a fair degree of accuracy on this account. The top of the plant is especially pale, much more so than normal freshly unrolled young leaves. In some cases the color becomes decidedly yellow. In this connection it must be stated that the pallid color referred to heretofore as characteristic of the diseased areas is not a yellowish green but a lighter or more dilute tint of the normal green. In plants which become markedly yellow a decided stunting of the whole plant takes place. At no time has a case been observed to terminate fatally, but certain considerable injury results from the lack of functioning chloroplastids, and where a large percentage of the plants are affected the loss due to decreased size of ears is appreciable. When infection takes place early in the growing season, partial or complete sterility of the ears results. This serious feature of the disease was first noticed in Louisiana in 1920. In May, 1920, the writer tagged 20 diseased and 10 healthy plants in a field of White Creole corn. The diseased and healthy plants were equally vigorous to all appearances at that time and were in the same rows, alternate diseased and healthy plants in the same row being selected as far as it was practicable. When the crop was harvested in August, 17 of the diseased plants were found to be completely sterile, while 3 of them had set a few scattered kernels. The 10 healthy plants were normal, excepting for slight corn earworm injury, and produced large well-filled ears (Pl. 96).

During the course of experiments in the greenhouse several cases of apparent recovery have been observed. Plants which became infected and exhibited the typical symptoms resumed their normal color after several weeks. These plants were held under observation until the ears were mature, but there was no recurrence of the mosaic symptoms. This interesting behavior was also noted in stools of crabgrass (*Syntherisma sanguinalis*) and foxtail (*Chaetochloa lutescens*). There were no changes of growing conditions that could be correlated with these apparent recoveries. In this connection it may not be out of place to record that suckers from diseased stools of sugar cane and sorghum have been observed to come up with no sign of mosaic. These instances are by no means common, but several have been seen in both plants mentioned.

Insect Transmission of Corn Mosaic

The manner in which corn mosaic is transmitted to healthy plants and the relation of this disease to mosaic in other grasses was demonstrated by the following experiments:

Experiment 1.—On March 12, 1920, 12 corn plants of the variety U. S. Select No. 182 were placed in each of two insect-proof cages. All of the plants were from the same lot of seed furnished by the Office of Cereal Investigations.

The seed had been planted in one flat, and the seedlings were replanted in 5-inch pots on the date of removal to the cages. They were then 12 inches tall. About 12 individuals of *Aphis maydis* were carefully removed by means of a small camel's-hair brush from sorghum plants affected with mosaic to each corn seedling in one of the cages. The sorghum plants had been infected by aphids from mosaic sugar cane. Twelve aphids were transferred in the same way from healthy sorghum to each of the corn seedlings in the adjoining control cage. On March 28, 6 of the 12 corn seedlings in the first cage showed typical signs of mosaic in the two youngest leaves. On April 6, 8 of the plants, or 66⅔ per cent, were typical cases. The 12 control plants remained healthy up to the time of removal several weeks later.

Experiment 2.—On April 6, 1920, 20 corn seedlings, variety U. S. Select No. 182, in 5-inch pots were placed in each of two insect-proof cages in the greenhouse. Several specimens of *Aphis maydis* were transferred from infected corn plants to each corn seedling in the first cage. Aphids from healthy corn in another greenhouse were placed on each corn plant in the second control cage, which was used as a control. On May 4, 7 of the corn seedlings in the first cage were found to be infected. On May 28, 15 of the 20 plants were observed to be unmistakable cases. The aphids had increased enormously in both cages. Not a single case could be found in the control cage, nor had any appeared up to June 25, although the plants had been repotted twice and were approaching maturity.

These experiments demonstrate conclusively that provision is made for almost unlimited dispersal of the virus through the medium of the corn aphis. There is no reason for supposing that transmission in nature is limited to this insect or to this method. It is not yet known whether the virus can survive the winter in seed, but experiments are now under way that may throw some light on this phase of the problem. It has been proved that the virus of corn mosaic is identical with that of sugar-cane and sorghum mosaic, so that even if it is found not to be seed-borne, perpetuation of the disease in the perennial grasses would explain its appearance on corn in the spring.

Artificial transmission of the disease by means of inoculation with expressed cell sap of affected plants has not been attempted for corn. This method has proved successful in sugar cane, however,[1] and there is little doubt that the infectious material is contained in the cell sap of corn. Just what this infectious material is can not be stated definitely, but the evidence points strongly toward a living organism. No evidence incompatible with this view has been put forward for any mosaic disease, excepting the failure to demonstrate any visible organism.

CONTROL

Control measures for this disease must be based fundamentally on the removal of sources of the inoculum. So far as is known the only sources of inoculum are the living host plants. Destruction of these plants, then, will effectively

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[1] Brandes, E. W., "Artificial and Insect Transmission of Sugar-Cane Mosaic," in Jour. Agr. Research, V. 19, No. 2, pp. 131-138. 1920. Literature cited, p. 138.

eradicate the disease from any region. Practically, the destruction of all affected host plants presents almost unsurmountable obstacles. An immense amount of sugar cane is now infected in the River District of Louisiana and in southern Georgia. Destruction of large numbers of plants by roughing or plowing up is viewed with great concern by the planters, most of whom oppose any plan to control the disease by eradication. The substitution of immune varieties of corn as well as cane does not offer any immediate solution, since the most susceptible varieties happen to be the ones most esteemed. Elimination of this disease is dependent upon the education of the planter to an understanding of its seriousness. When this is accomplished public sentiment will permit of the passage of compulsory roguing and quarantine laws, which will be necessary before any hope can be entertained of eliminating the disease.

[L. O. K.]

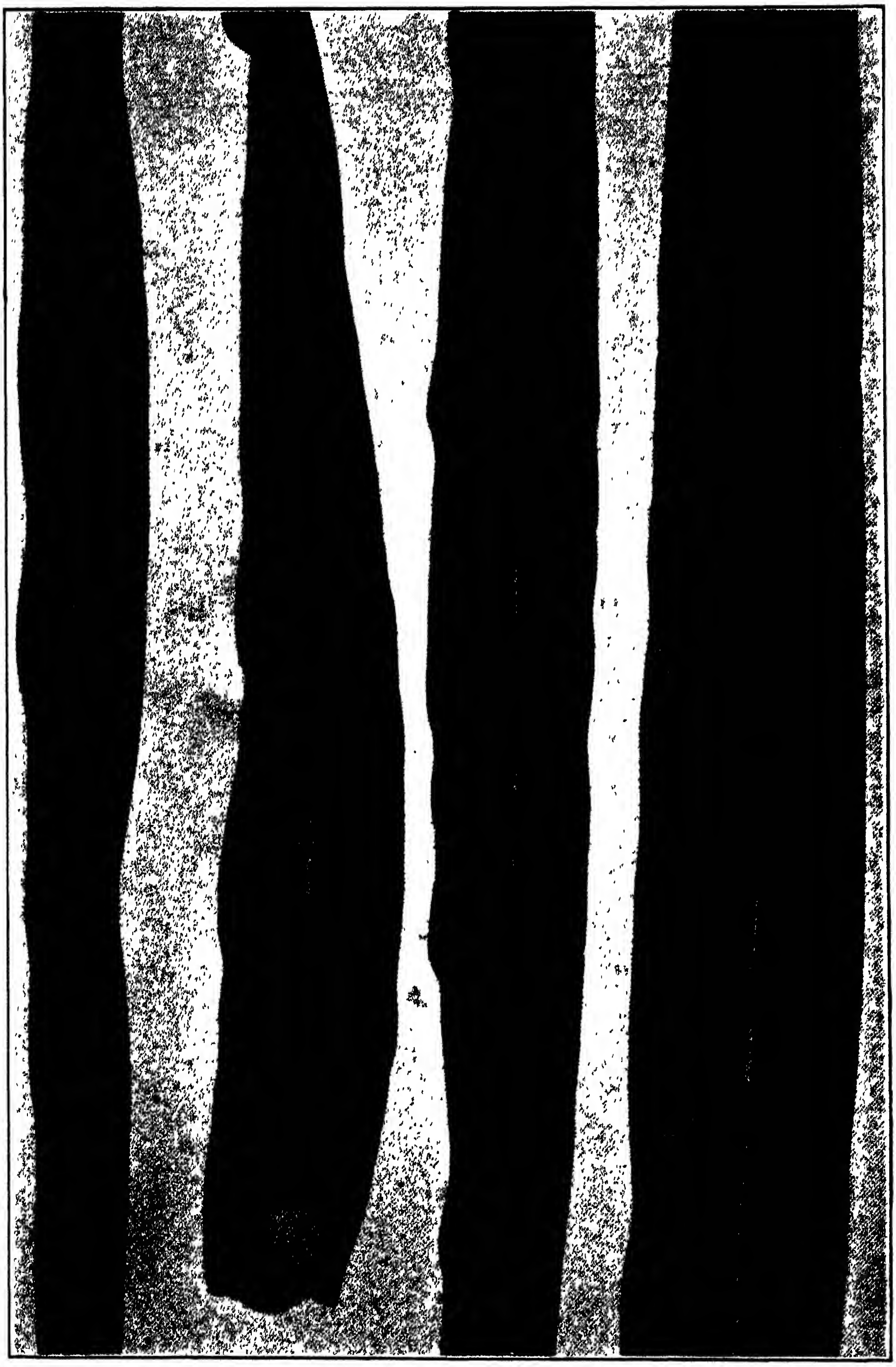


Plate 95. Mosaic Disease of Corn: The first leaf at the left shows the typical interrupted streaks of normal green in a pallid green background. The next leaf shows a more irregular, mottled pattern. In these specimens the normal green was similar to "nickel green" and the pallid green was similar to "rejame green" in Ridgeway.[1] The two leaves at the right are from a healthy plant and are presented for comparison.

1 Ridgeway, Robert, "Color Standards and Color Nomenclature," 43 p. 53 col. pl. Washington, D. C., 1912.

Plate 96. Mosaic Disease of Corn: Effect of early infection on the ear. White Creole variety.

The three ears at the top were produced by plants naturally infected in the field. In 17 out of 20 marked plants no kernels at all were developed.

The two lower ears are typical of all ears produced by healthy plants in the same row with the diseased plants.

Sugar Cane Diseases in Porto Rico.

The three following articles, treating of sugar cane diseases in Porto Rico, are reprinted on account of their general bearing on certain local problems which are receiving critical attention at the present time. The results of Mr. Matz's investigations on the cane root disease corroborate our findings insofar as the parasitic relation of a Pythium *to the root rot disease is concerned. We have not, however, yet found a vascular organism corresponding to the suspected* Plasmodiophora *discussed by Mr. Matz in the article entitled "A New Vascular Disease of Cane."*—C. W. C.

SUGAR CANE ROOT DISEASE.[1]

By F. S. Earle.

For several years past attention in Porto Rico has been so centered on the damage caused by the sugar cane Mosaic or Yellow Stripe disease that there is danger of overlooking the even more serious losses caused every year by the so-called root disease. This trouble is always with us. There is not a cane field in the Island that is not more or less affected by it. It is the cause of the dying out of the cane in so many fields that necessitates such frequent replantings. If it were not for root disease we would be today cutting twenty or thirty ratoon crops from each planting of cane as was done in the early days of the cane industry on this Island, and is still being done on virgin lands in eastern Cuba and in Santo Domingo. The expense of these frequent replantings is by no means the only loss caused by root disease. It is safe to say that one form or another of the troubles known under this collective name is causing a loss of tonnage on every acre of cane now growing in Porto Rico. Few cane planters who really understand these facts will question the statement that this is by far the most serious problem that confronts the cane growers not only in Porto Rico but on old lands in all parts of the sugar-cane-growing world. Unfortunately the question is very complex and obscure. There is probably no other plant disease of equal importance about which so little is really known and concerning which such erroneous ideas have long passed current in plant-disease literature. Some chance discoveries recently made in connection with studies of the cane mosaic have thrown new light on this most important subject and it seems opportune at this time to attempt a review of the entire problem.

Symptoms.

The symptoms of root disease are sufficiently well known to most cane

[1] Journ. Dept. Agr. Porto Rico, 4:3-27, 1920.

planters, yet they are not easy to accurately define. In the earlier stages they amount to little more than the slowing down of the normal growth of the cane. They are exactly the symptoms that would be expected when cane is planted on old worn-out lands without proper fertilizers. In other words, they are the preliminary symptoms of mal-nutrition, a lack of vigorous growth and a paling or slight yellowing of the leaves from the dark-green characteristic of cane in full vigor. These symptoms will be accentuated in dry weather, especially if this follows a period of excessive rains or in spots that have suffered from insufficient drainage. Bad drainage always intensifies the trouble from root disease. If drouth continues the leaves will begin to roll up during the middle of the day on the worse-affected spots. Later the lower leaves will die prematurely but will usually still hang to the stalk, not falling like normally matured leaves. The old leaf sheaths near the ground will often be found to be matted together and cemented to the stalk by a conspicuous white, mould-like fungus mycelium. Still later the tips and margins of the remaining living leaves will be seared and brown and the general color becomes quite yellow. When rains come this diseased cane may regain its color and continue to make some growth, but it never regains full vigor. As maturity of the crop approaches another phase of the trouble presents itself. The terminal bud on the more feeble stalk dies and this is followed by the rotting of the soft terminal tissues. This "top rot" is well known and is often incidentally referred to in cane-disease literature, but it has never been satisfactorily explained. Of course, a top rot, especially in young cane, when it is usually referred to as "dead heart," is often caused by injuries from the moth borer (Diatraea). A top rot of young overshaded suckers is also often caused by the fungus *Sclerotium Rolfsii,* which is everywhere present in cane fields. The top rot referred to above, however, comes from neither of these sources, but in the opinion of the author is the direct result and culmination of the symptoms that have so long been known under the collective name of "root disease." Soon after the dying of the top the black pustules of the fungus *Melanconium* appear on the stalk, usually beginning at the top of the stalk, following up the work of the top rot, but sometimes first appearing near borer injuries or on sun-scalded areas, and "rind disease" finishes the work of destruction by completely rotting the stalk unless harvesting quickly follows the appearance of top rot. The losses sometimes following from top rot and rind disease, which is now to be considered as the final manifestation of "root disease," are clearly shown by the notes (see page 260) on the variety experiment at Santa Rita, when, as early as December 10, before most of the mills had begun grinding, some of the more susceptible varieties were a total loss and where in the 90 plots of the standard Rayada the estimates showed an average of 29.4 per cent of top-rot stalks. Finally, after a severe case of root disease, the cane stubble fails to ratoon, or at best ratoons very poorly. Such stools must be dug out and replanted if a ratoon crop is expected. This replanting of ratoons is carefully attended to in Porto Rico, where it is part of the usual plantation routine. In Cuba it is frequently neglected, with the consequence that great vacant areas soon appear at the worst diseased spots in the field. These are locally known as

"sabanas," and they increase in area from year to year till the field is finally abandoned and plowed up.

The symptoms of root disease may then be summarized as follows:

1st. A slowing down of growth and lack of vigor, accompanied by a more or less pronounced yellowing of the leaves.

2nd. The rolling up of the leaves at mid-day during periods of drouth.

3rd. The premature dying of the lower leaves which remain hanging on the stalk and usually by the cementing of the leaf sheaths by a white fungus mycelium.

4th. A leaf burn causing the dying and browning of the tips and margins.

5th. Top rot, the dying of the terminal bud, followed by a soft stinking rot of the soft growing tissues.

6th. Rind disease, the appearance on the stalks of *Melanconium* and other fungi causing the rotting of the stalk.

7th. Failure to ratoon.

Historical.

During the first half of the last century the cane variety variously known as Caña Blanca, Bourbon or Otaheite, came to be grown very extensively in practically all of the tropical sugar-producing countries. It is a variety particularly well adapted to the rich porous soil of newly-cleared forest or so-called virgin lands, where it grows with great rapidity, giving a heavy tonnage of cane which yields a good percentage of sugar and which has unusually good milling qualities. Unfortunately, however, its root system is not adapted to the conditions found in old compacted soils. In one sugar-producing country after another this variety has given down, often with an apparent suddenness that has caused a serious crisis in the sugar industry, and it has been necessary to replace it by kinds better adapted to the compacted condition of old partially exhausted soils and more resistant to the complex troubles usually known under the name of Root Disease. Such a crisis occurred in the islands of Mauritius and Bourbon as early as 1846. In Porto Rico the outbreak in the Mayagüez district of the so-called epidemic of 1872 was clearly a manifestation of root disease. Similar crises have occurred in Jamaica and other of the British West Indies. In Java the problem was complicated by the presence of the Sereh disease and the Yellow Stripe or Mosaic, but the present custom of taking no ratoon crops but replanting the field annually has clearly largely come from the effect of root disease. In Cuba the abandonment of the Caña Blanca has been equally complete on all of the older cane lands, but as such a great area of virgin land was available for new plantings no sudden crisis resulted from a forced change of varieties. Fields of Caña Blanca (Otaheite) may still be found on the new lands of Eastern Cuba, but even here it is being rapidly replaced by the Crystalina. In Porto Rico this variety which was once so universally planted has practically disappeared except in certain loamy irrigated soils of unusually good texture on the south coast and in limited areas of the richer hill lands of the interior. Even here it does not ratoon well, but usually has to be replanted every year. The

entire question of varietal resistance to root disease is so important that it will be discussed under a separate heading.

Wakker in Java seems to have been the first investigator to assign a definite cause to sugar cane root disease (Arch. V. Java Suikerindus, 1895). He found a small gill-fungus or mushroom growing on the trash at the base of diseased stalks which he considered to be the cause of the trouble. He named and described this fungus as *Marasmius sacchari* n. sp. His work has been accepted and followed by most subsequent investigators, and to this day the terms root disease and Marasmius disease are used interchangeably in most publications on cane diseases.

During the years 1899-1902 Albert Howard was investigating sugar cane and other plant diseases for the Imperial Department of Agriculture of the West Indies with headquarters in Barbados. He seems to have been the first to identify our West Indian Root Disease as being identical with the trouble in Java. He found and identified *Marasmius sacchari* Wakker, and carried out a series of experiments that convinced him that it was the true cause of the trouble. In this he has been followed by Lewton-Brain, Bancroft, Tempany, Stockdale and other pathologists who have been connected with the British West Indian Department of Agriculture.

During the years 1904-1906 root disease was investigated in Cuba by Cook and Horne. They found an abundant white mycelium involving the bases of the old leaf sheaths, but during this period found no fruiting bodies of the *Marasmius.* (Estac. Agro. de Cuba Bull. 7, 13, 1907.) They did find, however, the fructifications of another Hymenomycetus fungus, *Peniophora* sp., which they suggested as a possible cause for the disease. This was not supported by experimental evidence.

In Circular 18 Horne refers to this fungus again as probably being *Hypochnus sacchari.* In the second report of the Cuban Station (Inf. Ann. Esta. Agr. de Cuba 2:81--, 1909, Horne again discusses root disease. He reports the finding of abundant fructifications of *Marasmius sacchari* Wakker in the fall of 1908 not only at the base of cane suffering from root disease, but also on Johnson grass, Para grass and Guinea grass. He inclines to attribute the root disease to this fungus rather than to the *Peniophora,* but again gives no experimental proofs.

In Hawaii in 1905 Lewton-Brain published as Bul. 2 of the Sugar Planters' Experiment Station a paper entitled "Preliminary Notes on Root Disease in Hawaii." At this time he had not found fruiting bodies of Marasmius, but he considered the disease as identical with the West Indian root disease with which he was familiar in Barbados. The following year Marasmius fruiting bodies were found in connection with the root disease. These were named *Marasmius Sacchari var. Hawaiiensis* by Cobb. (Sugar Station Bull. 5:214, 1906.) In this same publication, which is entitled "Fungus Maladies of the Sugar Cane," Cobb describes at great length a stink-horn fungus which he calls *Ithyphallus coralloides* n. sp. and to which he ascribes the principal role as cause of the root disease. The whole question was discussed and illustrated most elaborately, but without one word of proof to establish the causative relation of this fungus, which is one of the last that could reasonably be expected to be a parasite.

Cobb's work has not been confirmed by other investigators, so this profusely illustrated paper may be dismissed as one of the curiosities of pathological literature.

In 1908 R. H. Funton discussed root disease in Louisiana (Expt. Sta. Bull. 100). He ascribed it to a *Marasmius*, but to a different species, which was determined as *M. plicatilis* Wakker.

In Porto Rico this disease has been extensively studied by both J. R. Johnston and J. A. Stevenson during the time of their connection with the Insular Experiment Station. In their joint paper on Sugar Cane Fungi and Diseases of Porto Rico (Jour. Dept. Agri. Porto Rico 1-(4) 1917) they enumerate and describe *Marasmius sacchari* Wakker, *Himantia Stellifera* Johnston sp. Nov., *Odontia saccharicola* Burt, *Odontia Sacchari* Burt and some other Hymenomycetous fungi as occurring at the base of cane stalks and apparently in connection with root disease, but they say (p. 189), "The exact status of root disease with respect to the parasitism of *Marasmius, Himantia, Odontia* or possibly other forms is uncertain, and while it is generally held that *Marasmius* at least is a true parasite, really definite evidence is lacking. Studies under controlled conditions must be carried out working with pure cultures of the fungi which has not yet been possible."

Stevenson in his more recent papers has used the term "Deterioration" to cover part of the symptoms that have been above described and has attempted to separate them from what he calls "Root Disease." This he considers as being caused by parasites, but as quoted above he does not consider it as proven that either *Marasmius* or the other conspicuous Hymenomycetes connected with the disease are its true cause.

In the *Hawaiian Planters' Record* for July, 1919, Mr. H. L. Lyon has published a paper entitled "A Preliminary Report of the Root Rot Organism." In this paper he describes and figures an organism which he does not name but assigns to the *Chytridineae* which he considers "the primary cause of the Lahaina disease (of cane) and pineapple wilt throughout these Islands and perhaps in other tropical countries as well." The vegetative stage of this organism consists of small naked plasmodia either rounded or irregular and elongated, which occur two or more together in the same root cell. These plasmodia are believed to fuse and to then form either a sporangium or a resting spore, since these are uniformly found only one in each host cell. The sporangia soon give rise to motile zoospores. The resting spores are thick-walled globular bodies. They were kept under observation for several months, but it had been impossible to induce them to germinate. They occur in the soft tissues of the root often near the growing point. When the presence of this organism causes the death of a root it is soon completely destroyed by secondary organisms.

The above hasty review of the literature of Root Disease is in no sense intended as a complete bibliography, but it is believed that it covers all of the different views that have been published regarding this disease, or as perhaps it had better be called this complex of diseases. It should be added that white grubs (*Lachnosternum*) and other root-eating insects often produce somewhat similar symptoms, the results to the cane being much the same whether the roots

are killed by fungi or are eaten off by insects. A certain amount of such root insect injury is doubtless often included under the general name of root disease. Mealy bugs too (*Pseudococcus*) are very abundant in most cane fields and aid in creating that state of debility that accompanies the first stage of root disease.

The technical studies on certain organisms connected with root disease that are reported on another page of this publication by Mr. Matz represent a distinct advance in our knowledge of this most important complex of diseases. When Mr. Matz came to the Insular Station a little over a year ago the present writer took every occasion to impress on him the overshadowing importance of root disease as a sugar-cane problem and pointed out the entirely inadequate treatment of the question in plant-disease literature. He personally collected and brought to the laboratory much of the material on which these studies are based and has watched every step of the investigation with closest interest. He therefore feels competent to discuss the results and to express a decided opinion on the following points:

1st. *Marasmius* is at best a very feeble parasite. It may overrun new healthy roots or other organs without killing them. The same may be said of the so-called "stellate fungus" and of the other Hymenomycetes that form a conspicuous white mycelium on cane trash and at the base of cane stalks.

2nd. The killing of the roots which is so marked a feature in "root disease" is usually caused by various species of *Rhizoctonia* and sometimes by a species of *Pythium*. These are the well-known causes of the damping off of seedlings and cause heavy losses in tobacco and vegetable seed beds, but they have not before been connected with a disease of cane.[1] This seems most remarkable in view of the fact that some one of these species has been isolated from almost every diseased cane root from which cultures have been made and that in

[1] Since the above was written Hawaii Federal Station Press Bulletin 54 (issued December 9, 1919) has been received. It is by C. W. Carpenter and is entitled "Preliminary Report on Root Rot in Hawaii." In this interesting paper Mr. Carpenter attributes the root rot of cane, taro, bananas and rice and the wilt of pineapples in Hawaii all to the action of a species of Pythium which he considers as probably P. DeBaryanum. In discussing Lyon's paper he expresses the opinion that the resting spores found by the latter in cane and pineapple roots are in reality the oospores of this *Pythium*. Oospores have been produced abundantly in Mr. Matz's cultures here of *Pythium* from diseased cane roots. They certainly strikingly resemble the bodies figured by Lyon, but they are always accompanied by a conspicuous mycelium. Furthermore, they germinate readily. These facts make us doubtful whether or not Carpenter and Lyon are discussing two distinct organisms. Mr. Carpenter's paper, however, corroborates Mr. Matz's conclusion that *Pythium* is one of the active agents in killing cane roots.

A review of additional literature not accessible when the above note and paragraph was written shows that Pythium has long been known to attack cane roots. In discussing the Sereh disease in Java, Dr. M. Treub in 1885 (Med. Slands Plant, Buitenzorg 2:30-35, 1885) refers at some length to *Pythium* on the roots as a possible cause. In 1896 Dr. J. H. Wakker in a paper entitled De Schimmels in de Wortels van Het Suikerriet (Med. Proefs. Oost-Java (n. series) 21), gives a fine plate and a long discussion of *Pythium* as the cause of the killing of cane roots. The more conspicuous *Marasmius* seems, however, to have attracted his attention more strongly, as it has that of most subsequent investigators, and no subsequent mention of *Pythium* as a cane fungus has been found in the literature until that of Carpenter as mentioned above.

every case they have promptly killed every cane root on which pure cultures have been planted. Nothing could be more convincing than that these heretofore unsuspected species and not *Marasmius* and its allies are the true root-killing agents. We can only conclude that previous workers have done little in the way of making cultures from dying cane roots or they could have hardly failed to have detected these fungi which are so easily isolated and grown in artificial cultures.

This very satisfactorily clears up what may be considered as root disease proper, viz., the actual killing of the roots. The conditions under which this occurs and its relations to cultural practices will be discussed in another paragraph. The above organisms are all facultative parasites, and as such may be controlled at least to some extent by cultural methods.

3rd. The finding of a strict parasite within the vascular bundles of cane suffering from root disease was an entirely accidental and unexpected result from some anatomical studies of cane tissues made in connection with the investigation of the sugar-cane Mosaic (see Journ. Dept. of Agr. Porto Rico, Vol. III, 4, Oct., 1919). At first it was thought that this organism might have some connection with the mosaic disease since it was originally discovered in the tissues of an advanced case of mosaic. Later, however, it was found not once, but very many times and from widely different localities in cane that was suffering from root disease but that was absolutely free from mosaic. The evidence is conclusive that this organism is connected with the former disease but not with the latter.

Its life history has not been fully worked out. The vegetative stage consists of a yellow plasmodium which occupies the larger vessels of the vascular bundles, often completely filling them for considerable distances. Infected bundles may be easily detected with a hand lense, or even with the naked eye, in either cross or longitudinal cuts on account of their peculiar orange-yellow color. This is quite distinct from the reddening of the bundles that so often accompanies any mechanical injury. These plugged bundles are more abundant near the base of the cane, especially in the part which develops below ground, but they have also been found in the roots, and they can often be traced for long distances up into the cane, occasionally, in mature cane, almost to the terminal bud.

This plasma is multi-nucleate. After a time each nucleus surrounds itself with a rounded mass of the cytoplasm and begins to divide first into two, then into four, and finally into a mass of dense granules. At the same time a cell wall is being formed and the result is a globose, thick-walled resting spore. The cell wall is smooth and hyaline, but the content is so densely granular that the spore is dark and opaque. They are produced in great numbers and remain imbedded in the cytoplasm, which finally becomes somewhat hardened and gum-like. So far these spores have resisted all attempts to germinate them. The remainder of the life-history can therefore only be conjectured. It seems most probable that when these infected canes and cane stubbles rot in the soil these resting spores are liberated and in their own good time germinate probably by the formation of motile zoospores. These probably find their way into new cane roots and thus start the infection of other canes. It is evident also that when infected canes are cut up and used as seed for new plantings that the

disease could be propagated in the new field by the continued growth of the original plasma.

If the above hypothesis is correct and these resting spores do break up into motile zoospores the organism would have to be classed among the *Myxomycetes* or Slime moulds. The only recognized genus to which it could be referred would be *Plasmodiophora.* It differs from the known species of this genus in the much larger size of the spores and in the fact that it causes no enlargement or distortion of the cells of the host. It seems best to withhold a final opinion as to its name and systematic position until its life history has been more fully determined.

The resting spores of this organism are so very similar to those figured and described by Lyon for the supposed Chytridiaceous fungus discovered by him as a cause of root disease in the Hawaiian Islands that it was at first assumed that we had found the same organism. This, however, can hardly be the case. We have found nothing resembling the sporangia and definitely formed phasmodia which he figures. The resting spores of his organism occur singly in the parenchyma cells of the young roots and the epispore is irregularly thickened. Our organism is in the vascular bundles, not the parenchyma. The plasmodium is indefinitely continuous, often for a distance of many centimeters. The numerous resting spores have a smooth cell wall of equal thickness throughout. It seems clear that this organism belongs in the Slime moulds and not in the *Chytridiaceae.* It is, however, remarkable that two such similar but distinct organisms are causing serious damage to sugar cane in different parts of the world and that both had so long escaped detection.[1]

It is not possible as yet to express a fixed opinion as to the damage being done by this vascular bundle parasite, nor as to its exact role in the complex we are considering under the name of "root disease." It is not probable that it is an active agent in the actual killing of roots. In fact, it is quite certain that this is not the case. The actual root killers are facultative parasites, and as such their action is largely inhibited when the cane is in full vigor. The bundles fungus is doubtless one of the many contributing causes to lack of vigor and thus may be indirectly responsible for loss of roots. Whether its action is merely mechanical, simply resulting in the plugging of the bundles it occupies, or whether it may secrete injurious substances we do not know. If the former, an occasional plugged bundle will cause little or no harm, but if many of the bundles are invaded the result would inevitably be the rolling up and withering of the leaves and finally the death of the terminal bud. It seems probable, therefore, that this bundle fungus is correlated with the baffling condition known as "top rot" rather than with "root rot" proper.

Whatever the damage it may be doing it is widely scattered in Porto Rico, having been found in every cane-growing district where a search has been made for it. It is interesting to note that the old Caña Blanca (Otaheite or Lahaina) is particularly susceptible to it. It was found to be very abundant in the few stalks of this kind that have survived in the experimental plots at the Mayagüez Station where it had been interplanted among ~~the~~ other kinds as a check and

[1] See note on page 254.

where it practically all failed to ratoon at the end of the first year. This particular field, by the way, is said to be the one where the famous epidemic of 1872 first made its appearance. This may be only a coincidence, but it at least suggests this as one of the factors in that outbreak.

The habit of growth of this fungus makes it certain that it has been widely transported in seed cane. It therefore probably has a wide distribution in all cane-growing countries. It should certainly be carefully searched for by all investigators. Its presence indicates the great unwisdom of taking seed cane from old, neglected fields where it is quite certain to be more abundant than in new plantings. It also probably explains the better results usually obtained from planting "top seed," since it is comparatively rare for this organism to reach the top joints of the cane. Where the entire cane is used for planting the butt cut should certainly be rejected, since this is much more likely to be infected.

4th. The above discussion throws light on the much-discussed problem of "top rot."[1] It seems entirely probable that this bundle inhabiting, *Plasmodiophora*-like organism is the original cause of "top rot," aided, of course, by the root-killing fungi and the other factors of "root disease" that unite to lower the vitality of the cane. The writer is well aware that no positive proof has been given as to the causal agency of the bundle fungus in producing "top rot." He only wishes to point out the strong probability that this is the fact.

In cases of "top rot" the withering leaves of the terminal bud spindle soon show numerous, scattered, minute black spots which under the microscope prove to be the fruiting bodies of some fungus. As noted by Stevenson in his discussion of "wither tip" (Jour. Dept. Agr. Porto Rico, 1:207), this usually is found to be either *Sphaerella sacchari* Speg. or *Periconia sacchari* Johnston.

At about the time that these fungus specks become visible a stinking bacterial rot occurs in the soft tissue about the growing point. This rot only involves the soft tissues. Sometimes the disease is checked at this point, the rotted top falling away while the joints below remain sound, the lateral buds soon pushing into new shoots. More often, however, the black pustules of "rind disease" appear on the joints below the rotten tip and this soon completes the destruction of the stalk.

Clearly these bacteria and fungi so uniformly associated with "top rot" are saprophytes and agents of decay, but it is very probable that they are also facultative parasites and are able to attack cane tops that have been weakened by other causes without waiting for death to occur. This point needs further study. Whether the fungi or the bacteria or both are real killing agents has not been determined. In any event it seems certain that they cannot attack cane that is in full vigor and health.

Many references occur in the literature to a supposed bacterial top rot of cane, but no proof exists that there is a specific disease of this nature apart from the fact that bacteria are always present in the soft, rotting tissue.[2] The whole

[1] Since the above was written, the Gumming disease or Sugar Cane Gumosis has been found in Porto Rico. (See J. Matz, Insular Station Circ. 20, 1920.) This also causes a top rot, but such cases can be distinguished by the flow of gum from cut surfaces of the stalks.

[2] Mr. Noel Deerr has informed the writer that a contagious bacterial top rot exists in Demerara, but his studies regarding it have not been published.

subject needs much careful investigation. The above discussion is intended to be suggestive rather than final.

5th. In the preceding paragraph the statement is made that "rind disease" usually sets in to complete the work of destruction caused by "top rot," the predisposing causes for this last condition being here held to be "root rot" and the presence of the bundle inhabiting *Plasmodiophora*-like organism. The "rind disease" here referred to is assumed to be caused by *Melanconium sacchari* Mass. The discussion of this fungus in plant-disease literature has been involved with many needless and really inexcusable errors. It seems clear that this fungus has nothing to do with either *Trichosphaeria, Thielaviopsis, Diplodia* or *Colletotrichum,* although eminent mycologists have frequently expressed a contrary opinion. This is a very common saprophyte, growing everywhere on dead cane trash. It is not an active parasite, but can attack enfeebled cane tissue before it is quite dead. It often follows borer injuries, but in these cases seldom is able to pass the nodes, being confined to the one injured joint. Where canes have been so weakened by "root disease" that they have fallen a victim to "top rot" the vitality is so lowered that the *Melanconium* is usually able to quickly invade and destroy the entire cane.

Varieties differ greatly in their power of resisting "rind disease," the Otaheite or Caña Blanca being particularly susceptible. This question will be further discussed in a subsequent paragraph.

To what extent the "red rot" caused by *Colletotrichum falcatum* Went. has been confused with "rind disease" it is not easy to determine, especially since they often occur together, in which case this fungus is likely to be overlooked, being obscured by the more conspicuous *Melanconium.* Apparently, *Colletotrichum* is not as injurious here as in many other cane-growing countries. It is, however, known to occur, and Stevenson reports the presence of three other unnamed forms of this genus as occurring on sugar cane in Porto Rico. Their distribution and economic importance should be given careful study.

6th. *Failure to ratoon.* Cane suffering from the advanced stages of "root disease" (including "top rot" and "rind disease") seldom ratoons well and in many cases fails entirely, thus causing the necessity for the early abandonment of the planting. This represents an even greater financial loss than the yearly shortage in tonnage. It may be considered as the final culmination of this series of disasters. It completes the picture of the complex of trouble as we now understand them that are grouped under the comprehensive name of "Sugar Cane Root Disease."

The Resistance of Cane Varieties to Root Disease.

Ever since root disease was first recognized it has been noted that different varieties were very differently affected by it, some being very susceptible while others were comparatively resistant. The old favorite Otaheite, Caña Blanca, Bourbon or Lahaina as it has been variously called, has always suffered more severely than any other kind in general cultivation. It seems to be particularly

susceptible to all phases of this complex of maladies. Its root system is delicate, and while well adapted to rich porous lands that are well supplied with humus, it quickly succumbs to the attacks of *Rhizoctonia, Pythium* and other root-killing fungi when the soil becomes old and compacted. It was never a strong ratooner and on unfavorable soils it often completely fails to ratoon even after the first cutting. In addition it proves to be a favored host for the vascular bundle fungus that has been above described, and the stalks are particularly susceptible to the *Colletotrichum* red rot and to the *Melanconium* rind disease. One or another of these troubles or a combination of them has caused its failure and abandonment in practically all cane-growing countries. The opinion has been widely expressed that this variety was degenerating. The facts, however, do not support this idea. Where all conditions are favorable it grows with its old-time vigor. It is simply a susceptible variety only adapted to a narrow range of conditions. It is the old, long-cultivated soils that have deteriorated and not the Otaheite cane.

It was the failure, often the sudden and disastrous failure, of this old favorite that first forced serious attention on other kinds and that has led in so many countries to the extensive production of new seedling varieties. Many of these new kinds have come to be extensively planted. In fact, the sugar industry of many regions is now based almost entirely on some of these new kinds. Their success has been almost entirely due to their resistance to root disease. It is a remarkable fact that among the multitude of new kinds produced and tested so few have surpassed or even equaled the old standard varieties in sucrose content and purity. New kinds are everywhere pushing out the old standard kinds, Otaheite, Crystalina, Rayada and Morada (purple), not because they are richer, better milling canes, but because they are more resistant to root disease and so give better tonnage for a longer series of years.

Much attention has been given to this subject in the British West Indies, and the reports from the different agricultural stations there are filled with notes on the resistance or susceptibility to the root disease of different varieties in different localities and different seasons. In the publications of the Porto Rico Stations casual mention can be found regarding the resistance of various kinds, but no comprehensive study of the question seems to have been made under our local conditions. A cooperative planting of 171 varieties made at Santa Rita, Guánica, in the irrigated district on the south side of the Island, for the purpose of testing their resistance or susceptibility to the Sugar Cane Mosaic, has been reported on in Bulletin 19 of the Insular Station. At the time of the last inspection reported in this bulletin, August 10, 1919, it was evident that some kinds were not doing as well as others aside from the effects of the mosaic infection.

It was suspected then that root disease was also at work, but as yet it was only in the preliminary stages, no signs of "top rot" or "rind disease" having appeared. Subsequent visits showed that the combined effect of the root disease and the mosaic were going to result in heavy losses from "top rot." It is not considered that the mosaic was in any sense a primary cause of this top rot. Its presence was simply one more factor in lowering vitality of the cane. Some

white grubs (*Lachnosterna*) were also present and helped to secure the total injury which ended in disaster for most of the kinds in these plots.

Rhizoctonia had been isolated from cane roots from this field early in the season and it was found that many of the canes were infected by the vascular bundle parasite. On December 10, 1919, about the time when Central Guánica is usually actively grinding the *gran cultura* plantings, a final inspection was made and the per cent of "top-rot" stalks in each row was estimated. It will be remembered that every third row in these plots was planted with Rayada seed infected with Mosaic in order to insure the equal exposure of the other kinds to that disease. There were 90 of these Rayada plots. The per cent of "top rot" was estimated in each of these. In 8 of them it was placed as low as 5 per cent. One was a complete loss, 100 per cent. The average of the estimated loss on the 90 plots was 29.4 per cent, so that figure is given in the following table. Twenty-six kinds had been cut for seed and had ratooned, so notes could only be taken on the condition of the ratoons. It is to be presumed that most of these kinds would have shown good resistance to the root disease had they been standing. Most of the top-rotted canes had developed rind disease and were fast becoming a total loss. The average condition of the field was deplorable, though it was planted on very fine land and had had the best of irrigation and cultivation.

* * * * * * * * * * *

In discussing the above table[1] it must be borne in mind that practically all of this cane, excepting only the Kavangire, was heavily infected with Mosaic, which by lowering its vitality had greatly contributed to this disastrous result. It is considered, however, that this has only accentuated the effects of the root disease and has brought out with unusual clearness the resistance or susceptibility of these different kinds. The 26 kinds cut for seed in September were those considered most promising by the Agricultural Staff of Guánica. Had they remained standing they would doubtless all appear in the resistant lists. It is known from two seasons' observations at the Mayagüez Experiment Station that Java 36 and Java 234 are almost equally as resistant to root disease as the Kavangire. These three clearly make a class apart in their almost complete immunity to root disease and in their great ratooning power. It will be noted that the Kavangire is of straight North Indian blood, while the other two are hybrids with another North Indian cane, the Chunnee, as staminate parent. The so-called Egyptian cane (see Bulletin 19, p. 15) is probably Java 105 P.O.J., and if so is another of this set of hybrids. It promises to be equally resistant with the others but unfortunately it was not included in this experiment: we therefore have—

LIST 1.—*Varieties practically immune to root disease*:

Kavangire	**Java 105 P. O. J. "Egyptian"**
Java 36 P. O. J.	**Java 234 P. O. J.**

Of the remaining broad-leaved canes there are only four which showed no cases of top rot.

[1] A five-page table of detailed statistics not reprinted.

List 2.—*Highly resistant varieties, showing no top rot*:

B. 4596	G. C. 127
F. C. 214	G. C. 1539

List 3.—*Resistant varieties, showing general good conditions and only 2 per cent to 5 per cent of the top rot*:

B. 3578	G. C. 1254
B. 6450	G. C. 1486
F. C. 79	G. C. 1491
F. C. 193	G. C. 1522
F. C. 312	Java 228 P. O. J.
Fortuna Seedling	P. R. 292
G. C. 888	Sealey Seedling

The kinds cut for seed and which would probably have fallen in either 2 or 3 follow, as—

List 4.—*Varieties cut for seed, probably resistant*:

B-109	F. C. 277 **
B-3859	F. C. 322 **
Cavengerie	G. C. 606
D-435	G. C. 701 *
F. C. 95	G. C. 1313 *
F. C. 104	G. C. 1486 **
F. C. 133 **	G. C. 1504
F. C. 178	G. C. 1513 *
F. C. 199 **	G. C. 1518 **
F. C. 202	G. C. 1521
F. C. 204	G. C. 1545 *
F. C. 239	P. R. 260

Those marked with an "*" in the above list show a complete stand of ratoons, those with "**" have a complete stand and show superior vigor.

These lists include the only kinds that would have made a satisfactory commercial crop under the trying conditions of this experiment. The others grade all the way from a 15 per cent or 20 per cent reduction in crop to a complete loss. But for its extreme susceptibility to Mosaic disease Yellow Caledonia would assuredly have been found in one of these lists, since it has very considerable resistance to root disease. This table should have a great practical interest for every cane grower in Porto Rico, since it illustrates so forcibly the supreme importance of selecting the proper variety for planting in order to avoid very serious possible losses. It is seldom that circumstances combine to produce such striking results as were given by this experiment, but, on the other hand, there can be no question but that root disease is exacting a heavy toll in practically every cane field in the Island.

One of the most impressive lessons from this experiment is the outstanding superiority in resistance of the canes of North Indian parentage. Kobus in Java seems to be the only cane breeder who has realized and taken advantage of this most important fact. The continued indiscriminate breeding of new seedlings of the ordinary broad-leaved tropical type of canes does not seem to be leading to any advantage. Crossing a vigorous North Indian cane like Kavangire on the Crystalina, which represents the best of the rich-juiced, broad-leaved tropical canes, should lead to much more favorable results. Such crosses could be easily made by simply-planting the two kinds in adjoining rows, since the Crystalina is

usually sterile to its own pollen. The present writer is only temporarily in Porto Rico. It is unlikely that he will ever have the opportunity to undertake cane breeding, but he strongly urges this cross on the attention of those who do continue in this work.

Remedial Measures Against Root Disease.

It is clear from the discussion under the last heading that the planting of resistant varieties is likely to prove the most effective remedial measure. It is also clear that the varieties descended from the slender, narrow-leaved North Indian canes show greater resistance to this complex of troubles than the stouter, sweeter, broad-leaved tropical kinds, though many of these last show very satisfactory resistance.

Making a complete change in variety is often difficult and it may be costly. It always takes considerable time. It must be admitted, too, that none of the resistant kinds so far tested is really equal to Crystalina and Rayada as desirable milling canes. It is of great practical importance, therefore, to consider what other remedial measures are possible and how satisfactory they have proven in actual practice.

It must be remembered that so far as we know all of the organisms that cause injuries in connection with this disease, with the one exception of the vascular bundle fungus, are facultative parasites. That is, they cannot attack tissues that are in vigorous growth, but only those that have become weakened from some cause or that have reached such a state of over maturity or senility that the vital processes are lowered. All of the root killers and all of the organisms found in the dead tops and in rind disease and red rot belong in this category. It is a fact of general knowledge that diseases caused by facultative parasites are as a rule best controlled by improved cultural methods. Cane-root disease is no exception. The more abundant use of properly balanced fertilizers; careful attention to drainage where needed, as well as the avoidance of unnecessary ditching; most important of all in Porto Rico, sufficient cultivation with implements to keep the soil open and porous and to prevent crusting; and the use of irrigation when soil or climate conditions demand it will go far to prevent the enormous losses now caused by this complex of diseases. On the contrary, the factors that contribute most largely to these losses are lack of fertility, lack of suitable drainage, hard, compacted, unworked soils, severe drouths, and injuries from insects or other diseases such as white grub, mealy bug or Mosaic. The author's experience in Porto Rico is limited, but he has observed innumerable instances in Cuba on old lands so exhausted that cane plantings run out after two or three light cuttings, where a reasonable annual application of fertilizer and good cultivation has not only resulted in considerably increased crops at the first cuttings, but has prolonged the life of the fields from two or three to eight or ten years. He has published in Circular 19 (Oct., 1905) of the Estación Agronómica de Cuba a photograph showing on the one side a vigorous field of ratoons going to their fourth cutting and on the other a grass field with one lone remaining stalk of cane. Both lots were planted at the same time. The one only showing grass was not fertilized, the other received 500 pounds per acre of a complete

chemical fertilizer when planted, but it had not been fertilized since, the residual effect of the one application still keeping the cane in comparatively good health and vigor, while the unfertilized cane had entirely disappeared. This was undoubtedly an unusual case, but it clearly illustrates the point under discussion, which is that a large percentage of the annual losses from root disease are easily preventable by following the simple agricultural practices mentioned in Circular 17 of this Station.

Unfortunately, the finding of a true parasite, the vascular bundle fungus, shows that not all of the losses can be prevented in this simple manner. Our studies so far do not indicate how serious a factor this may prove to be in the general complex, but it is entirely unlikely that it can be controlled by cultural methods. In the variety experiment at Santa Rita, the results of which have been already discussed, this organism was frequently found. The disaster which overtook that field notwithstanding fairly good cultural conditions seemed to depend on the complication with the severe infection of Mosaic disease rather than on the presence of this organism. The Mosaic disease by its influence in reducing vitality and inducing premature maturity is a factor exactly fitted to promote injury from root disease.

Aside from the selection of resistant varieties and the use of reasonably good cultural methods, one other point requires attention, and that is proper selection and handling of seed cane. The bundle fungus is undoubtedly transported and planted in the seed. There is less danger of this where top seed is planted and less danger when young plant cane is used than with old ratoons. In planting the entire cane for seed as in *gran cultura* the butt-cut should be rejected, as this is more likely to carry the bundle fungus and besides the bottom leaf sheaths are likely to be matted by the mycelium of *Marasmius* and other undesirable fungi. The seed cane, too, should be inspected and the butts should be cut off in the field where cut. The common practice of hauling the cane to the side of the new field and doing this work there is objectionable, since it leaves the infected butts and discarded canes on the border of the new field with every chance for infecting it.

Dipping seed cane in Bordeaux mixture will have little or no effect in preventing root disease. This treatment serves to protect the seed piece from the entrance of the pineapple-rot fungus (*Thielaviopsis*) or other rot-producing organisms. It can have no effect on the bundle fungus and will have little or no effect in preventing root killing by *Rhizoctonia*, *Pythium* or other facultative parasites.

Summary.

1st. Root disease as here understood is a complex including phases often known as Root Rot, Wither Tip, Top Rot and Rind Disease. These phenomena are caused by a number of facultative parasites, none of which attacks actively growing vigorous tissues. There is also a heretofore unknown true parasite inhabiting the vascular bundles. *Rhizoctonia* and *Pythium* are the usual root-killing agents rather than *Marasmius* and *Himantia*.

2nd. Cane varieties differ greatly in their resistance or susceptibility to Root Disease. The Otaheite or Caña Blanca is very susceptible. North Indian

canes like Kavangire and those with part North Indian parentage are very resistant or practically immune.

3rd. Remedial or preventive measures include—

A. The planting of resistant varieties.

B. Better cultural methods to overcome facultative parasites.

C. Proper seed selection and handling.

INVESTIGATIONS OF ROOT DISEASE OF SUGAR CANE.[1]

By J. Matz.

The root-disease problem of sugar cane has engaged the attention of many workers in the past, including the work of A. Howard on "Some Diseases of the Sugar Cane in the West Indies," published in 1903 in the Annals of Botany V. 17, pp. 373-412, in which the author gives an account of his experiments to establish a relation between *Marasmius sacchari* Wakker, and the root disease of cane in Barbados. From those experiments it appears that *Marasmius* is capable of causing damage to the sugar cane during certain unfavorable seasons. Under favorable conditions for the growth of the sugar cane plant the presence of the fungus on the plant did not seem to have a deleterious effect. The question arises if unfavorable seasons and unfavorable conditions in the field alone are not sufficient to produce an effect that might be similar to that which may result from a fungus attack on the roots of the plant. The fungus *Marasmius sacchari* is very common in a large part of the cane fields of Porto Rico and it has generally been taken to be the cause of root disease here. Johnston and Stevenson while describing root disease of cane in the Journal of the Department of Agriculture of Porto Rico, Vol. 1, No. 4, 1917, express doubt as to "the exact status of root disease with respect to the parasitism of *Marasmius, Himantia, Odontia,* or possibly other forms, * * * while it is generally held that *Marasmius* at least is a true parasite, really definitive evidence is lacking." During the past year an attempt was made to determine, if possible, the exact nature of root disease of cane, and the facts thus far learned are of sufficient interest to warrant their publication.

What Is Root Disease of Cane?

By root disease of any plant it is usually understood to mean decay of roots which result in either the rotting of the basal part of the plant or in a mere stunting and subsequent withering of the whole plant. In either case the symptoms should be clear enough as not to confuse it with other diseases. In cane there are many plants which could easily be taken as affected with root disease that may not be suffering from root disease at all. Borers of various kinds,

[1] Journ. Dept. Agr. Porto Rico, 4:28-40, 1920.

drouth, lack of cultivation, gum disease, top rot, and lack of drainage produce effects that may be taken for root disease. The cane plant as a whole has such a structure that injuries to the lower portion, whether caused by mechanical agents such as boring insects or by the physical condition of soil, or whether by fungi and bacteria which either clog up the conducting channels or fibers, thus starving the plant or simply decompose the roots through parasitism, the effects on the plant as a whole in all cases would be drying of leaves from the tips, top rot, stunting and shortening of the joints and a multiplicity of short sprouts. Therefore to distinguish root disease proper from other troubles of the cane which arise in the root region the term root disease is restricted here to mean a decomposition of roots taking place on account of the invasion of fungi. The symptoms of root disease therefore are primarily a decomposition or lack of healthy roots, dry leaves and stunted appearance of the cane. Top rot may also result indirectly on account of lack of sufficient roots to take up and conduct necessary water and food to the plant. The binding of the lower leaf sheaths has been generally taken for a symptom of root disease; that is, when *Marasmius sacchari* was taken as the parasitic cause of the disease. That symptom is not necessarily an accompaniment when another fungus is concerned with the decay of roots. Cane ratoons which exhibit all the effects of root disease, being stunted and having the lower portions of the stalks covered with adhering dry leaf sheaths and yet binding was not observed and the yellowish white mycelium of *Marasmius* was not noticed in between them. It is, however, reasonable to assume that the same ratoons had they grown in low and moist locations and if *Marasmius* had been present in that soil that binding would have taken place, as the fungus thrives well on dead cane leaves and stalks. It is quite possible that under unfavorable conditions of growth the cane plant may fall a prey to an organism which is not parasitic enough to be able to attack the cane had it grown under conditions conducive to strength and vigor. Such cases no doubt exist. But the semi-parasitic organisms do not add much more damage to the amount which is already caused by the unfavorable conditions, which may be poor drainage, lack of water and no cultivation or undesirable varieties planted on unsuitable soil lacking in plant food elements. The important factor in true root disease should be an organism which is capable of attacking essential roots and destroying them. With this point in view a search was made to find and isolate microorganisms from the interior of young but partially affected roots of cane. This effort was rewarded by finding *Rhizoctonia*, a root-destroying organism in the tissues of young roots, on seven different occasions, and *Pythium* sp. on two occasions. At the same time *Rhizoctonia* species were isolated from a large variety of plants other than cane, proving that this form genus is widely distributed in soils of Porto Rico.

The Isolations of Fungi from Cane Roots.

The first isolation trial was made in December, 1918, immediately after the writer had become connected with the Insular Experiment Station, from cane at the Santa Rita estate near Yauco. The cane plants were only a few months old from a *gran cultura* planting. The leaves did not show any abnormal appear-

ances at that stage, except yellow-stripe disease in some plants. On pulling up some plants, both yellow-striped and healthy, it was observed that the roots of some, though numerous, were mostly brown and partly decayed. Although the brown coloration is natural with older roots, the young and fleshy rootlets, however, were stained an unnatural red and the root cortex was dissolved and decomposed in part. Two plants were brought to the laboratory, and the younger and red-brown rootlets were cut off washed in running water, and with a flamed scalpel bits of the reddish and soft tissue were planted in corn meal agar plates. In about two days three fungi were observed in the plates. One was *Rhizoctonia* with its characteristic even mycelium and anastomosing side branches, another was a *Pythium,* latterly determined as such by its fructifications, and several colonies of *Trichoderma.* These three fungi were transferred to several tubes containing sterilized green bean pods. The *Rhizoctonia* transfers began to form yellowish sclerotia in about four days. At first these sclerotia were composed of loose but short and stout hyaline hyphae, later the masses became more compact and took on a deeper color. In about 3 weeks the mycelium in the tube became buff brown; and the sclerotia became darker and have attained a size of 1 to 3 millimeters. They are rounded and covered with a lighter growth of short hyphae. The culture presents all the general characters of the well-known *Rhizoctonia solani,* of which the writer has a culture which was isolated in Florida and compared with a culture of the same from Dr. B. M. Duggar of the Missouri Botanical Garden. Whether this cane *Rhizoctonia* is identical with or is a different strain from *R. solani* is reserved for another paper to be published in the future.

Inoculation Experiment.

Before searching any further for more fungi on cane roots an inoculation experiment was made to test the relation of the above-named three fungi to cane root decay. Rayada cane seed, each consisting of at least one entire internode and two nodes, were cut with a sharp knife about one-half inch above and below their respective nodes. These pieces were washed for 15 minutes in a 1 : 1000 solution bichloride of mercury, rinsed in running water and planted in steam-sterilized soil in six-inch pots. Three seed pieces were inoculated with the above *Rhizoctonia,* three with *Pythium,* and three with *Trichoderma.* This was done by placing a bean pod culture of one of the organisms on the seed piece and covering it all with about one inch of soil. The pots were watered and kept covered with paper for three days from inoculation. On the fourth day the top layers of soil were removed and the young roots, some of which had attained one inch in length, were examined. It was found that where *Rhizoctonia* and *Pythium* were used some of the young roots were red and soft. Small pieces of the latter were examined with the aid of the microscope and it could plainly be seen that the two fungi had entered and grown into the interior of the roots, causing a decomposition of the cells of the fleshy parts of the root. The characteristic *Rhizoctonia* mycelium, with its almost perpendicular branching and distinct walls, could be seen to ramify in and between the cells of the roots in the parts where that fungus was used as the inoculum, and the stout, uneven and

hyaline, non-septate mycelium of *Pythium* was observed to have grown around and between many root cells in the pots where this fungus was used. The fungus *Trichoderma* did not produce any visible change in the roots of the cane.

Having that much success with this first trial, another experiment was made, using the three above-named fungi and in addition pure cultures of *Marasmius sacchari* and *Odontia saccharicola.* Again *Rhizoctonia* and *Pythium* gave positive results, while *Trichoderma, Marasmium,* and *Odontia* did not affect the young roots. In this experiment six seeds were inoculated with *Rhizoctonia,* six with *Pythium,* three with *Marasmius,* three with *Odontia,* three with *Trichoderma,* and three were left as checks. Two strains of *Marasmius* were used; one was from a culture growing in pure state on sterilized cane leaves in flasks, the other was isolated by the writer from spores of hymeniums collected in a cane field at Río Piedras. The two strains were similar in all appearances, the first one probably having come from mycelium commonly found on leaf sheaths and basal parts of cane stalks. The method employed to obtain spore cultures from *Marasmius* and *Odontia* was by making a spore print on sterilized corn-meal agar. A drop of agar was placed on the inside of a Petri dish cover and a portion of the hymenium was stuck onto the agar. Then the top was placed over a corn-meal agar poured plate permitting the spores to drop on the surface of the agar in the bottom dish. With fresh hymeniums a spore print on sterilized agar was thus obtained in 24 hours. Single spores could then be transferred from the edge of the print where they are not too thickly sown. Both fungi were grown on sterilized green bean pods. The growth of *Marasmius* in pure cultures, from single spores, was producing white strands similar in appearance to the fungus usually found in connection with binding of the lower leaf sheaths. Other cultures from the white mycelium, usually taken to be *Marasmius,* were also made, and there was such an agreement of characters between these and the cultures from spores that the writer is inclined to the general belief that the common leaf-binding fungus in Porto Rico is no other than *Marasmius sacchari.* Further proof of the identity of the two forms was had by the fact that a culture of mycelium from matted leaf sheaths developed the spore-bearing stage of *Marasmius sacchari* when placed in soil in pots in which cane was growing. The cultures of *Odontia* spores were rather slow growing, producing a short, grayish and thin growth of mycelium on bean pods, after a while becoming water-soaked and giving to the bean pod itself an oily or more or less transparent aspect. There were no formations of mycelial strands or threads in these cultures. And the writer could not find any similarity of character between these pure cultures and the thread mycelia commonly encountered on cane soils in the field.

When the plants inoculated with *Rhizoctonia, Pythium, Trichoderma, Marasmius,* and *Odontia,* in the experiment mentioned above, were examined it was noticed that in the *Marasmius* pots, although the white threads of the fungus had penetrated through the upper three or four inches of soil, the growing roots of the cane seed were not affected in any unusual way. Mycelium was observed on some roots, but no rotting took place. However, after three months from inoculation there could not be seen any appreciable difference in the growth between any of the inoculated plants and those used as checks. A liberal amount of

water has regularly been applied to the plants. When the water was cut off for two or three days, the ones inoculated with *Rhizoctonia* showed less vigor. Four months from inoculation the pots inoculated with *Marasmius* produced the fruiting stage of the fungus; at the same time the cane plants were among the tallest and most vigorous ones. * * *

All the plants in the last experiment were later taken out of the pots and their root systems examined. It was apparent that the roots from the plants infected with *Rhizoctonia* were fewer in number and that many of the longer roots were brittle and decayed; the same was noticed where *Pythium* was applied to the soil; in the case of *Marasmius*, although the fungus mycelium was plainly visible in amongst the soil particles, yet the roots did not show as much decay as in the first two; the same was true with the *Odontia* and *Trichoderma* infected plants. The roots of the check plants were normal. The plants were then set out in the field. All of them made a uniform growth with the exception of a larger number of dead lower leaves being present on those which were prviously infected with *Rhizoctonia.*

At maturity the cane, all of which made a very good stand, was cut and allowed to ratoon. In the ratoons an unevenness of growth in the center of the plot was observed. This unevenness was no doubt due to soil conditions, as the effect of the previous inoculations were entirely lost during the first season of growth after the transplanting to a new location. In this small plot of cane there became evident a stunting of the cane in a central area, a phenomenon which is not unusual in cane fields. In this particular case, the uneven stand in the cane was evidently due to a very compact soil, which became more so in the center of the plot during a season of heavy rainfall.

In order to make close observation of the relation of the above-mentioned fungi to root decay of cane a series of moist chamber inoculations were made as follows: Seed pieces of cane containing one or two buds were sterilized in a solution of 1 : 1000 bichloride of mercury and placed in sterilized and moist glass jars. Cultures of *Rhizoctonia, Marasmius,* and *Pythium* were placed on the cane seed and the jars were covered with glass. *Rhizoctonia* has in two weeks invaded the growing rootlets, the threads of the fungus growing on the whole length of the rootlets. Instead of being white or yellow the rootlets turned reddish brown and the smaller roots, or those which have arisen after the fungus has had time to develop its growth, did not attain any considerable length and they were abnormally brown instead of purple at the tips. Compact masses of the mycelium were plainly visible in the softened tissues of the attacked rootlets. Reisolations gave the same type of *Rhizoctonia* from these roots. *Marasmius* grew right alongside of the roots of seed on which it was placed, but there were no striking differences of any abnormal nature in appearance of these roots and the roots of seed in the check jars. Although the fungus mycelium of *Marasmius* was in contact with the roots there was no sign of decay in them. *Pythium* did not have the same injurious effect upon the roots as *Rhizoctonia* in this experiment. However, a few roots were observed to have been attacked and upon reisolation the same fungus was recovered. Experiments such as described above have been repeated several times, using different

varieties of cane, and employing other strains of *Rhizoctonia*. The results have not always been uniform, mainly due to the fact that other fungi and ferments would enter and cause decay of the seed pieces, thus preventing normal development of roots. On several other occasions the inoculum would not grow in the jars as described, due, perhaps, to an early chemical change in the seed itself.

That the condition of the seed piece in itself plays an important part in the health of the first series of roots that arise at the time of germination has been observed on several occasions. For example, in one experiment mature Otaheite seed were used in the jars, the seed being placed on one end in the bottom of the jars in about one-fourth inch of tap water. Not a single seed out of 24 germinated and the roots did not make much headway before they became arrested in growth and finally decayed. On the other hand, the same treatment when accorded to Rayada and Caledonia did not produce in them any growth-inhibitory symptoms. The seed pieces of the latter two kept sound and their roots in most of the jars attained normal lengths and were abundantly side branched. However, the seed of these two varieties if infected with the yellow-stripe disease produced many short-lived, red roots when placed in moist jars as above. Of course, the cane bud produces its own roots after a while, but during the early stages of its growth it is dependent upon the mother seed piece and its root system in order to make good growth. If the seed piece is liable to become fermented sooner, either because of its natural lack of hardiness or because it was allowed to become weak on account of too prolonged exposure between the time it was cut and the time it was set in the ground, it is quite certain that it will give weak shoots which will be short lived mainly because such seed do not produce enough and vigorous roots.

Another form of *Rhizoctonia* was found in its sclerotial stage on the lower dead leaf sheaths of cane. Kruger[1] in describing diseases of cane mentions three diseases which are associated with three distinct sterile fungi but which produce sclerotia. One of these, causing the red rot of leaf sheaths and stalks, is *Sclerotium Rolfsii*, as can be plainly seen from Kruger's colored plate XIV. Another sclerotia-producing fungus he associates with the sour rot of the leaf sheaths. This fungus, he states, produces sclerotia of light orange-yellow color, are larger and softer than the former (*Sclerotium Rolfsii*). The fungus with the orange-yellow colored sclerotia is unknown to the writer. On pages 443-447 Kruger[1] describes and illustrates a disease under the name of sclerotia disease of sugar-cane leaves. The fungus associated with the disease is most likely identical with the *Rhizoctonia* under discussion. The thin mycelium of this fungus is hardly noticed, but its gray to dark-gray and sometimes gray-brown sclerotia which are more or less rounded, concave and sometimes ridged are commonly found in damp and shaded locations on dead leaves near and sometimes on the ground. The fungus was grown in pure culture from bits of sclerotia in corn-meal agar and on green bean pods. When a pure culture of the fungus was placed in sterilized soil in pots the mycelium grew rapidly in the soil and sclerotia were formed in large numbers on the moist surfaces of the soil and the walls

[1] W. Kruger, Das Zuckerrohr und seine Kultur. 1899, pp. 433-466.

of the pots. Pure cultures of the fungus were placed on seed cane in sterilized soil and the growth of the fungus on the young shoots and roots was observed. The shoots became reddish-brown and dry at their bases and began to dry at the tips as well. The fungus mycelium and sclerotia were adhering to the lower parts of the young cane shoots. Other seed planted at the same time and under similar conditions, but the soil in which these grew was not inoculated with the fungus, produced vigorous shoots. In order to prove whether this fungus is capable of attacking green leaves and their sheaths above ground, portions of growth of the fungus produced in culture tubes were placed on green leaves and sheaths of cane and covered with glass chimneys. The growth of the fungus on these was rather slow; it produced lesions of various sizes, the largest being one-half inch in length on one leaf. In all cases it produced one or more sclerotia which were identical with those from which the cultures were made.

Pure cultures of the same fungus were placed on young roots of cane seed placed in sterilized moist chambers. The fungus mycelium grew over the roots and it was noticed that many of the roots soon became partially brown. Upon examination it was found that the fungus has penetrated into the soft tissue of the roots, and portions of these when planted in agar gave the identical fungus upon reisolation.

Character of the Fungus.

The fungus agrees with the general characters of the form-genus *Rhizoctonia*. Stevenson in the Annual Report of the Insular Experiment Station, of 1917, page 138, describes the fungus as *Sclerotium griseum*. The fungus is, according to the description and herbarium specimens deposited by him at this laboratory, identical with the above *Rhizoctonia*. The sclerotia do not possess a distinct cortex, are not smooth and are homogenous in color throughout. When this fungus is grown in culture tubes on sterilized bean pods it presents a very similar appearance to the growth of *Rhizoctonia solani* with the exception that the latter is darker brown. Other forms of *Rhizoctonia* similar to the *Solani* type have been grown by the writer in pure culture and which were very light in color. The sclerotia of the above cane fungus are very irregular, flat and more or less loose in texture when produced in culture tubes on bean pods. Since this fungus agrees more with the form genus *Rhizoctonia* than with *Sclerotium*, the name *Rhizoctonia grisea* (n. comb.) is proposed.

Summary.

Sugar cane roots, like many other plants, are attacked by the well-known fungi belonging to the genera *Rhizoctonia* and *Pythium*.

These fungi are common in the soils of Porto Rico.

More than one form of *Rhizoctonia* has been isolated from diseased roots of cane.

A NEW VASCULAR ORGANISM IN SUGAR CANE.[1]

By J. Matz.

In studying the internal structure of cane affected with yellow-stripe disease and cane which was free from this disease but which was affected with top rot or rather dry top, it was observed that the annular and spiral tracheides and pitted vessels in the fibro-vascular bundles, in the lower internodes of both classes of cane mentioned, were plugged with an organism consisting of spherical orange-brown colored spores embedded in a yellowish hyaline matrix. Later this same occurrence was detected in roots of cane as well. Sometimes the vessels were filled with a mass of granular protoplasm containing all stages between numerous small immature ovate bodies of various sizes and the mature, spherical, larger spores. The larger spore bodies have more or less thickened, smooth walls with an interior of a darker, orange-brown mass of granular protoplasm; are uniformly spherical in shape, but vary slightly in size; they measure from 0.014 to 0.016 millimeters in diameter. The smaller bodies, when pressed out of vessels under a cover glass, vary in size and form. They vary in size from four microns in diameter to nearly the full size of the larger spherical bodies. In form the smallest are devoid of any distinct wall and appear like an irregular dense granule; however, the larger of these possess a densely granulated small center surrounded by a hyaline mass of cytoplasm which is several times thicker than the central granular part. At this stage the small bodies, owing to the soft consistency of their outer part, are mostly oval, due to pressure they exert on each other in the interior of the vessels. The cytoplasmic hyaline layer becomes thinner and the center larger as the individual grows into maturity. The actual growth of these organisms has not been observed, as the mature spherical bodies have not germinated in several attempts made, but as the various smaller immature and the spherical mature bodies have been found in the interior of the same fibro-vascular bundles and even in the same vessels, it is only reasonable to assume that they represent different phases in the life history of one organism. In examining fibro-vascular bundles it was found that the lowest portions contained the mature spore bodies and that these diminished and the smaller ones increased in numbers towards the upper part so that at the uppermost point of their visible penetration only granular cytoplasmic masses were found. In some bundles the organism appeared only as a mass of granulated nearly hyaline cytoplasm.

The presence of this organism can be detected in cane which shows, upon splitting lengthwise or cutting crosswise, bright yellow or orange-colored, sometimes reddish fibro-vascular bundles. These are usually located in the root region of the underground portion of the stalk. The number of orange or reddish-colored bundles in the cane examined were variable. Some canes showed only three or four colored bundles and in sectioning these it was found that they were plugged with the above organism only for about two or three inches through

[1] Jour. Dept. Agr. Porto Rico, 4:41-46, 1920.

the lowest nodes and internodes. Others have been found to be infested to a larger extent; that is, the organism was present in a majority of the bundles which were orange-colored or reddish and to a height reaching the uppermost nodes. The degree of prevalence of the organism in cane is no doubt due to whether the cane has been growing in more or less infected soils and whether the seed was infected with the organism before planting.

It must be stated that the fibro-vascular bundles of cane, due to various effects, become sometimes red, vinous or brown in color. To the naked eye it is sometimes difficult to distinguish between these and those which are infested with the above organism. Moreover, bundles infested with the latter are sometimes bright red, due to a later effect of the death of the phloem. Nevertheless, many specimens have been recognized in the field as being infected with the above organism by the symptoms described in the previous paragraph, and this diagnosis proved correct later with the aid of the microscope. A homogenous, jelly-like, sometimes colored substance is sometimes found in the vessels of injured cane. This substance differs from the above organism in its lack of granulation. Gumming disease can be distinguished by its yellow exudation.

The Distribution of the Organism in Porto Rico.

The first discovery of the organism was made in the fall of 1919 in yellow-striped diseased Cavengerie cane at Bayamón; later it was found at Río Piedras in non-yellow-striped cane of a Porto Rico seedling. It was also found at Mayagüez in the varieties Otaheite and Crystalina, at Santa Rita in Rayada, near Cayey in Rayada, near San Germán in non-yellow-striped Crystalina, and near Loíza in D-109. In all of these localities cane is known to suffer from what is usually known as "root disease." In looking for the organism it was observed that it occurred in cane which showed symptoms of stunting and the tops of which were either partially or totally dry, effects which are commonly attributed to root disease.

The Relation of the Organism to the Growth of Cane.

From the mode of occurrence of the organism in cane, and the manner of its plugging the conducting vessels in the vascular system of cane it is quite natural that an interference with growth should result. At first an attempt was made to germinate the spores of the organism in water, in sugar water, in cane juice, in fermented but sterilized cane juice, and in several agars, but no germination was observed to have taken place. Spores were kept in moist cells for over six months and no germination was observed to have taken place. Portions of cane stalks which contained bundles filled with the organism in its several stages were cut and placed in moist chambers together with healthy seed pieces of Rayada cane, and after five months it was found that the roots of the Rayada cane contained many of the spherical spores of the organism. Apparently a transfer of the organism from its original seat into the healthy cane had taken place. Inoculations with bits of infested bundles into six healthy canes were made at the basal regions of the latter. The six cane stools thus inoculated show marked stunting in contrast with other uninoculated canes growing along-

side of the former. The important fact is that the organism is able to plug the free passage of the fibro-vascular system in cane, as it is found in that condition in the field.

There seems to be no mention of such a phenomenon in sugar cane in literature on the subject of cane diseases. It is apparently an organism hitherto undescribed.

No mycelium of any kind has been observed to be directly connected with any of the spore forms of the organism. The spores are free in the vessels of the host plant, and the plasmodium is limited by walls of the vessels of the host. Therefore it agrees with the characters of the family *Plasmodiophoraceae*. It differs from *P. brassicae* in that it does not form galls and that it inhabits the vascular system of its host. The spores of *P. brassicae* are smaller than in the organism of sugar cane.

Name of the Organism.

Plasmodiophora vascularum, n. sp.

Description. The spores in their advanced stage in the interior of the vessels of fibro-vascular bundles are spherical with smooth, somewhat thick hyaline walls, evenly granulated or sometimes coarsely granulated in the interior, orange yellow, sometimes slightly brown in color, measuring 0.014-0.016 millimeters in diameter. Spores are embedded in a yellowish hyaline, at length hard matrix. Plasma is composed of a mass of granular cytoplasm, later developing into individuals composed of clear, cytoplasmic variable bodies having a dense, darker, granular center.

Habitat. Mayagüez, Río Piedras and other localities, in cane fields, Porto Rico. In vascular system of sugar cane, *Saccharum officinarum* Linn.

[C. W. C.]

Common Sugar Cane, *Saccharum officinarum*.*

Natural Order Gramina: nat. both Indies. This plant and its cultivation has been so long known in the West Indies, that it will be needless to say much of it. There are several species cultivated in the Island (Jamaica), which suit the various soils and climates. There are also varieties of this cane both as to size of the joints and colour; some being a yellowish white, and long jointed, others red and shorter jointed, and another sort Elephantine, with the culm thick, and knots approximate. There is also the Ribbon cane, the culm of which is curiously striped and variegated; but not much esteemed. The Otaheite and Bourbon canes are now very much cultivated, and found to be very productive.

* From Titford, Sketches towards a Hortus Botanicus Americanus, p. 37. (Published in 1811.)

SUGAR PRICES FOR THE MONTH

Ended April 15, 1921.

	96° Centrifugals		Beets	
	Per Lb.	Per Ton.	Per Lb.	Per Ton.
Mar. 17, 1921	6.265c	$125.30	No quotation.	
" 18	6.27	125.40		
" 19	6.02	120.40		
" 22	6.27	125.40		
" 28	6.265	125.30		
" 31	6.02	120.40		
Apr. 5	6.01	120.20		
" 6	6.02	120.40		
" 7	5.885	117.70		
" 8	5.7867	115.734		
" 9	5.77	115.40		
" 12	5.64	112.80		
" 14	5.63	112.60		

[D. A. M.]

THE HAWAIIAN PLANTERS' RECORD

Volume XXIV. JUNE, 1921 Number 6

A monthly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

Fern Weevil Parasite

A cable dated from Sydney, May 4, from Mr. Pemberton announces that he has found a parasite on the fern weevil *(Syagrius fulvitarsis)* and has shipped some by the S. S. Makura. This beetle was figured and described in the "Record" for June, 1920, pp. 299–300.

F. M.

Serious Cane Disease Reaches Philippines.

In a recent letter Mr. H. Atherton Lee announces the discovery of the downy mildew *(Sclerospora sacchari)* on sugar cane in the Philippine Islands. Up to the present time he has found this aggressive parasite in one cane field only. The particular field belongs to Japanese planters who imported the seed for planting the field from Formosa in 1920 and there is little doubt but that they imported the disease with the cane.

This disease was introduced into Formosa in 1908 or 1909 with cane cuttings brought from Australia and by 1912 had caused great damage to the sugar industry of Formosa, according to a bulletin issued by their Sugar Experiment Station. A description of this disease may be found in the Planters' Record, 12:257-265,1915.

Cane Seedlings and Bud-selection

There seems to be an impression current that from now on we are going to rely on bud-selection rather than on the growing of seedlings to supply our needs in new cane varieties. This is in reality far from the truth, for the rearing of choice seedlings and the application of bud-selection are two separate phases in the production of superior varieties of cane.

We must first grow seedlings in order to secure the many constitutional

varieties which our varied conditions require, then by bud-selection we can isolate in each of these varieties the superior strains.

No one would advocate an attempt to isolate a drought-resisting cane from H 109 by bud-selection, nor would they, by the same means, seek to isolate a strain from Striped Tip for culture at low elevations under irrigation.

We still rely on seedlings to supply our new varieties and on bud-selection to raise each new variety to its highest possible standard.

Experiments in Cane Planting.*

"In a report of different experiments in cane planting conducted in the island of St. Croix, West Indies, it was found that over an average of eight plots, cane grown from first ratoon plants gave an average of 54.8 tons per acre, as against 41.8 tons for plant cane cuttings, and 34.3 from those obtained from second ratoons. The variation, however, was greater in the case of the ratoon cuttings, namely, from 38.8 tons to 52.2; whereas in the case of plots derived from plant crops, the highest tonnage was 45.3, and the lowest 35.6 tons, being a difference of only 9.7 tons, as against a difference of 13.4 tons where first ratoons were used."

A similar experiment harvested at Wailuku two years ago, comparing seed from plant, ratoon, and cut back cane, showed results in favor of seed from ratoons. R. S. T.

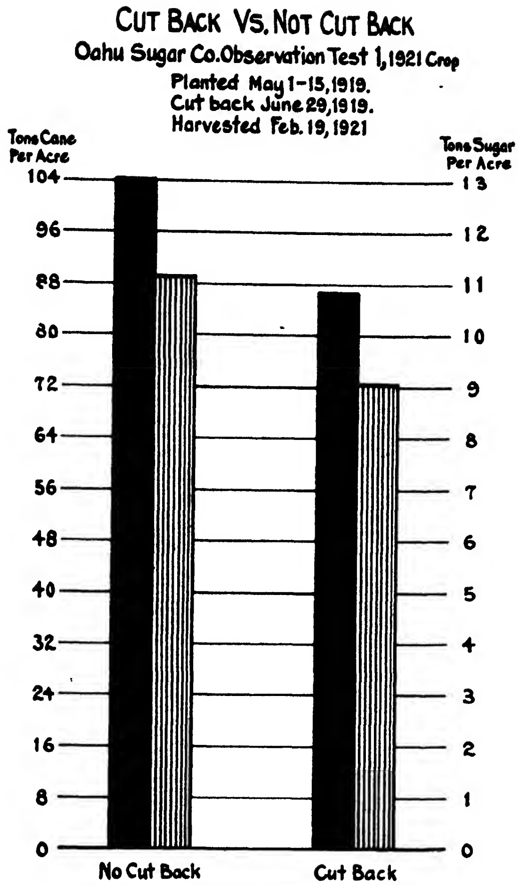
Cut Back Versus Not Cut Back.

In June, 1919, Oahu Sugar Company, field 15, had an excellent stand of dark green, vigorous growing H 109 plant cane. Planting took place from May 1 to 15. The cane received normal necessary irrigation, and on June 29 stood from 3 to 4 feet high. The elevation of the field ranged from 200 to 300 feet above sea level.

Then arose the question of cutting back. It was finally decided not to cut back the field, so an observation experiment was put in to see what would have happened had the field been cut back.

The experiment consisted of a narrow strip of plots, one watercourse

* From Queensland Agr. Jour., Vol. XV, p. 76, Feb. 1921.



in width, extending from the bottom to the top of the field. Every alternate plot was cut back. With the exception of cutting back, all plots received identical treatment.

At time of tasseling in the following December, not a tassel appeared in any of the plots.

During the first year of growth, there was a marked difference in appearance between the two sets of plots, the cut back being decidedly inferior in size of cane to the others.

During harvesting of the field, a few of the plots were harvested with the following results:

Plot	Yields—Tons per Acre			Loss Due to Cutting Back	
	Cane	Q. R.	Sugar	Cane	Sugar
Not Cut Back	104.24	9.35	11.14	.....	.....
Cut Back	86.93	9.58	9.07	18.31	2.07

In other words, if the field had been cut back it would have suffered a loss of 18.31 tons of cane or 2.07 tons sugar per acre. R. S. T.

Second Season Fertilization.*
Amount to Apply.

ONOMEA SUGAR CO. EXPERIMENT NO. 5, 1921 CROP.

This experiment is to determine the economical amount of nitrogen to apply during the second growing season. The first season a uniform dose of 88 pounds of nitrogen as B 5, a mixed fertilizer, was applied to all plots, while in the second season nitrogen was applied in the same form at the rate of 0, 44, 88, 132, and 176 pounds per acre.

The results show gains up to 132 pounds of nitrogen applied the second season, the latter amount causing a gain of 7.45 tons of cane or .53 ton sugar over no nitrogen. For the larger amount, 176 pounds, there is a further slight gain in cane, but the poorer juices cause a loss in sugar. The average yield for each treatment is as follows:

Plot	Treatment—Pounds Nitrogen		Yields—Tons per Acre			Gain over No N. During 2nd Season	
	1st Season	2nd Season	Cane	Q. R.	Sugar	Cane	Sugar
A	88	0	37.36	7.58	4.92	....	....
B	88	44	37.62	7.56	4.98	0.26	0.06
X	88	88	43.31	8.40	5.16	5.95	0.26
C	88	132	44.81	8.23	5.45	7.45	0.53
D	88	176	45.98	8.53	5.39	8.62	0.47

This experiment has now been harvested for three consecutive crops, the only variations being in the form in which the nitrogen was applied. In the first crop the second season nitrogen was applied as nitrate of soda, while for the past two crops it has been applied as B 5, a mixed fertilizer containing 11% N. 8% P_2O_5.

In the first crop,‡ on first ratoons, the profitable limit was found to be 132 pounds the second season, the increased yield over and above no nitrogen being 13.78 tons cane or 1.57 tons sugar. The 176 pounds of nitrogen gave a slightly greater yield of both cane and sugar but not enough more to repay the cost.

In the second crop,† on second ratoons, the gain from 132 pounds of nitrogen amounted to but 2 tons cane or .33 ton sugar. The 176 pounds of nitrogen gave a further increase to 3.9 tons cane but the poor juices caused no increase in sugar.

* Experiment originally planned and laid out by L. D. Larsen.

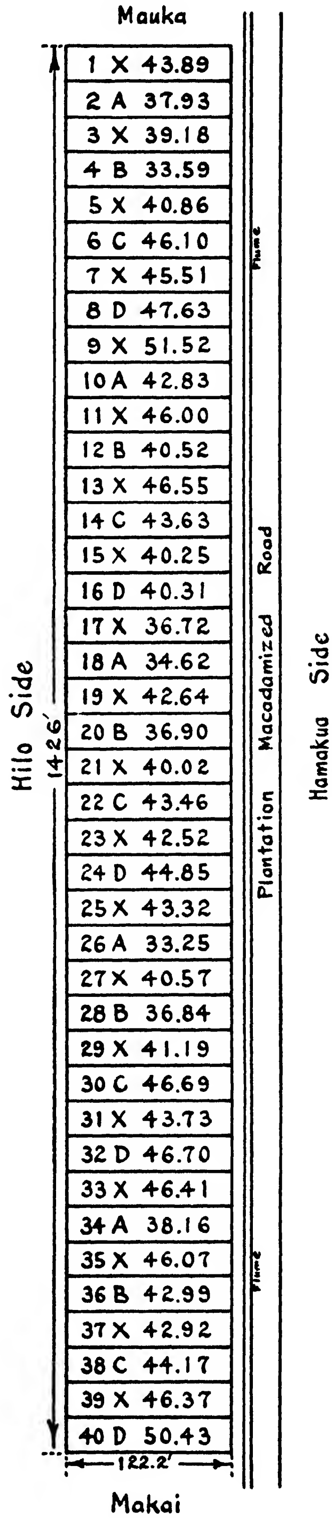
‡ Record, Vol. XVI, p. 346.

† Record Vol. XXI, p. 232.

AMOUNT TO APPLY SECOND SEASON

ONOMEA SUGAR CO. EXP. 5, 1921 CROP

FIELD 35.



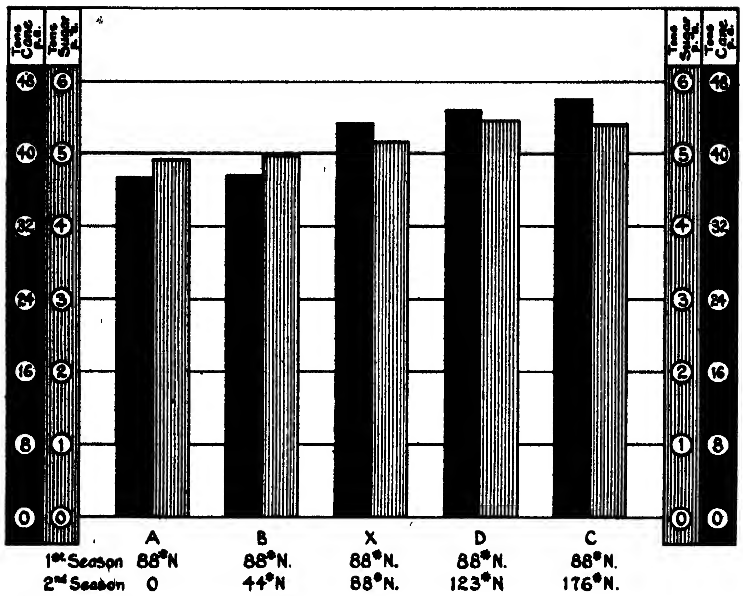
Summary of Results

Plots	Treatment		Yields – Tons Per Acre			Gain or Loss Over Adjoining X Plots	
	1st. Season	2nd Season	Cane	Q.R.	Sugar	Cane	Sugar
A	88# N.	0	37.36	7.58	4.92	- 6.27	- 0.27
B	88# N.	44# N	37.62	7.56	4.98	- 4.98	- 0.09
X	88# N.	88# N	43.31	8.40	5.16	0	0
C	88# N.	132# N.	44.81	8.23	5.45	+ 1.82	+ 0.33
D	88# N.	176# N.	45.98	8.53	5.39	+ 1.94	+ 0.15

AMOUNT TO APPLY SECOND SEASON

ONOMEA SUGAR CO. EXP. 5, 1921 CROP

FIELD 35.



In the third crop, on third ratoons, the gain from 132 pounds of nitrogen amounted to 7.45 tons cane or .53 ton of sugar. The 176 pounds of nitrogen gave a further increase in yield of cane to 8.62 tons but the poorer juices caused a decrease in the sugar yield.

The yields of sugar for each treatment for the three crops are summarized in tabular form as follows:

Treatment		Tons Sugar per Acre		
1st Season	2nd Season	1917 Crop	1919 Crop	1921 Crop
88 lbs. N.	0	6.21	6.15	4.92
88 lbs. N.	44 lbs. N.	6.72	6.04	4.98
88 lbs. N.	88 lbs. N.	7.35	6.29	5.16
88 lbs. N.	132 lbs. N.	7.62	6.48	5.45
88 lbs. N.	176 lbs. N.	7.87	6.47	5.39

In looking over these figures we see that much larger gains for increasing amounts of nitrogen were obtained in the 1917 crop than in either of the two succeeding ones. This is probably due to the fact that the fertilizer applied during the first season to the 1917 crop contained 4½% of potash. Eight hundred and twenty pounds of fertilizer were applied, thereby supplying 37 pounds of potash. The Onomea soils respond to potash in a marked manner. The fertilizer applied to the 1919 and 1921 crops contained no appreciable amounts of potash. It is therefore reasonable to assume that the nitrogen applied to the 1919 and 1921 crops could not be utilized to full advantage on account of lack of sufficient potash.

DETAILS OF EXPERIMENT.

Object:

To determine the most economical amount of nitrogen to apply in one dose in the second growing season.

Location:

Field 35 on Hilo side of Macadam road.

Crop:

Yellow Caledonia, third ratoons, long.

Layout:

Number of plots: 40.

Size of plots: 1/10 acre each, consisting of 6 furrows each 5.94 feet wide and 122.2 feet long.

Plan:

First season fertilization uniform to all plots at rate of 800 pounds B 6 per acre, in two equal doses.

Second season, B 5 applied in one dose as follows:

Plot	Lbs. B 5 per Acre
A	0
B	400
X	800
C	1200
D	1600

B 6=11% N. (4½% nitrate, 4½% sulfate, 2% organic).

PROGRESS OF EXPERIMENT.

July, 1919—Last crop harvested.
July 30, 1919—Experiment off barred.
August 8, 1919—First fertilization, 400 pounds B 6 per acre.
November 20, 1919—Second fertilization, 400 pounds B 6 per acre.
April 6, 1920—Third fertilization according to schedule, using B 5 instead of B 6.
February 25, 1921—Experiment harvested by W. L. S. Williams.

R. S. T. AND J. A. V.

Fertilizer Experiment—Number of Applications.

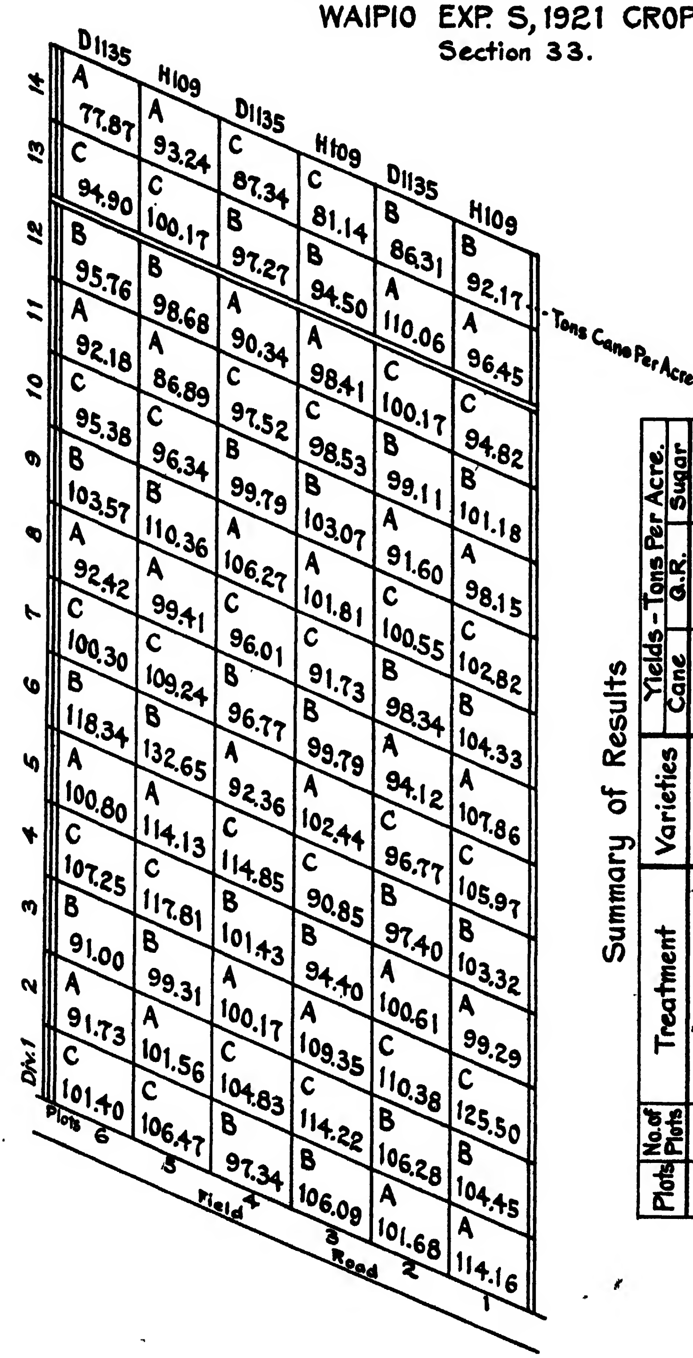
WAIPIO EXPERIMENT S.—1921 CROP.*

This experiment is to determine in how many applications a given amount of fertilizer should be applied. A total of 270 pounds of nitrogen was applied in one, two, and three doses in each of the two growing seasons, making a total of two, four, and six applications per crop to both the D 1135 and H 109.

All nitrogen was applied in the form of nitrate of soda according to the following schedule:

* Experiment planned by J. A. Verret. Results computed by R. S. Thurston and F. A. E. Abel.

FERTILIZER-NUMBER OF APPLICATIONS
WAIPIO EXP. S, 1921 CROP
Section 33.

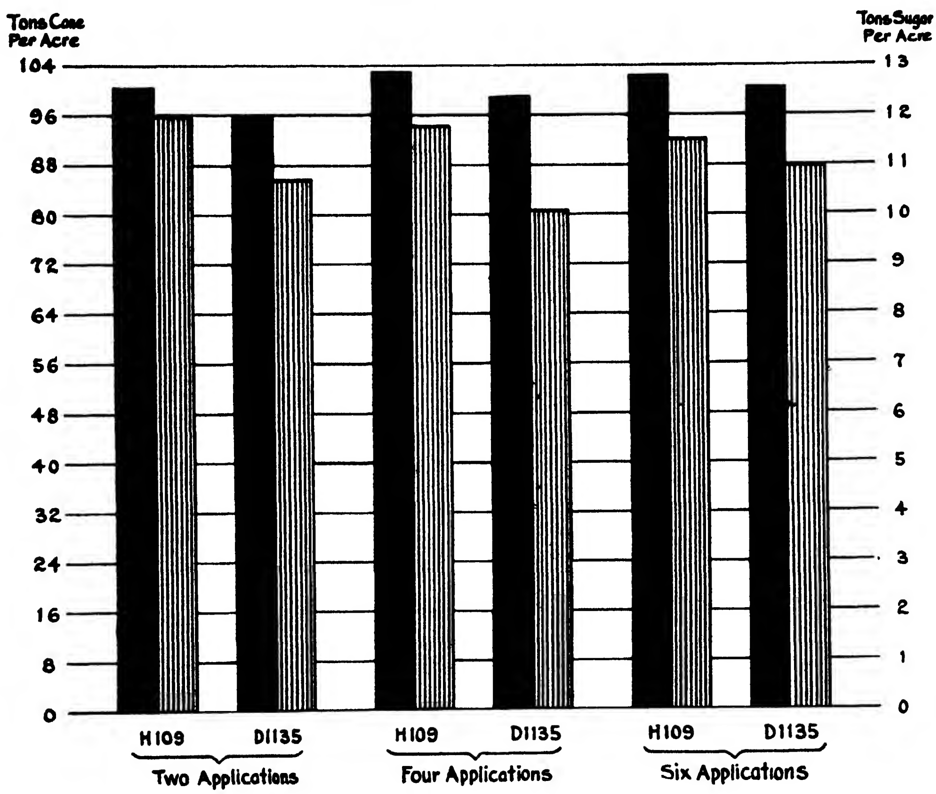


Summary of Results

Plots	No. of Plots	Treatment	Varieties	Yields-Tons Per Acre.		
				Cane	Q.R.	Sugar
A	28	270# Nitrogen Two Applications	H109	101.65	8.48	11.99
			D1135	95.87	8.96	10.70
B	28	270# Nitrogen Four Applications	H109	103.16	8.75	11.79
			D1135	99.19	9.84	10.08
C	28	270# Nitrogen Six Applications	H109	102.54	8.89	11.53
			D1135	100.55	9.16	10.98

Plots	Number Plots	Fertilizer in Pounds N. S. per Acre						Total Lbs. N. per Acre
		Sept. 1919	Nov. 1919	Dec. 1919	Feb. 1920	April 1920	May 1920	
A	28	1160	0	0	580	0	0	270
B	28	580	580	0	290	290	0	270
C	28	387	387	387	193	194	193	270

FERTILIZER - NUMBER OF APPLICATIONS.
WAIPIO EXPERIMENT S, 1921 CROP
Section 33.



When the yields of the two varieties are averaged for each treatment, the best sugar yields are obtained by applying the fertilizer in two doses, one each season. Applying it in two or three doses each season gives slightly increased cane yields but the poorer quality ratio causes a loss of at least .4 ton of sugar. (The better Q. R. of the C plots over the B plots is undoubtedly due to inaccuracy of sampling.) The average yields are as follows:

Plot	Number Plots	No. of Fertilizations		Yield—Tons per Acre		
		1st Season	2nd Season	Cane	Q. R.	Sugar
A	28	1	1	98.76	8.71	11.34
B	28	2	2	101.17	9.26	10.93
C	28	3	3	101.54	9.02	11.26

When, now, the yields of the two varieties are considered separately, H 109 is found to give practically the same tonnage of cane whether the fertilizer be applied in two, four, or six doses, divided equally between the seasons. But the larger number of applications causes a definite inferiority in the quality ratio, thus causing a definite and appreciable loss in yield of sugar. Thus, applying the fertilizer in six doses, besides the extra cost of application, causes a loss of .46 ton sugar when compared with the yield from two applications.

In the case of D 1135, the larger number of applications causes a pronounced increase in weight of cane, but not sufficient to overcome the loss caused by inferior juices, so the final result is in favor of two doses rather than four or six. The yields obtained by varieties are shown below:

H 109

Plot	Number Plots	No. of Fertilizations		Yields—Tons per Acre		
		1st Season	2nd Season	Cane	Q. R.	Sugar
A	14	1	1	101.65	8.48	11.99
B	14	2	2	103.16	8.75	11.79
C	14	3	3	102.54	8.89	11.53
			D 1135			
A	14	1	1	95.87	8.96	10.70
B	14	2	2	99.19	9.84	10.08
C	14	3	3	100.55	9.16	10.98

These results corroborate those obtained in the past and give further evidence showing that one application of fertilizer the second season is more profitable than two or three.

DETAILS OF EXPERIMENT.

Object:

To test the most profitable number of applications in which to apply a given amount of fertilizer.

Location:

Waipio, Section 33.

Crop:

D 1135 and H 109, fourth ratoons, long.

Layout:

Number of plots: 84.

Size of plots: 1/30 acre net, each plot composed of 8 lines.

Plan:

Plot	Number Plots	Fertilization—Pounds Nitrogen per Acre						Total Lbs. N.
		1st Season			2nd Season			
		Aug. 1919	Oct. 1919	Nov. 1919	Feb. 1920	April 1920	June 1920	
A	28	180	..	..	90	..	..	270
B	28	90	90	..	45	45	..	270
C	28	60	60	60	30	30	30	270

PROGRESS OF EXPERIMENT.

June 9, 1919—Last crop harvested.
September 2, 1919—First fertilization.
November 6, 1919—Second fertilization.
December 19, 1919—Third fertilization.
February 4, 1920—Fourth fertilization.
April 19, 1920—Fifth fertilization.
May 18, 1920—Sixth fertilization.
March 1–16, 1921—Experiment harvested by F. A. Paris and F. A. E. Abel.

[R. S. T.]

Cyrtorhinus in Hawaii and Some Factors Acting Against It.

By F. Muir.

The first colony of *Cyrtorhinus mundulus* was liberated on the 12th of July, 1920, and a few more on the 19th. These were known to have produced one generation in the field, and after that they seem to have disappeared. Since then a number of colonies have been turned loose on Oahu and Hawaii, and they have maintained themselves for some five or six generations, but they have not increased or, so far as we have discovered, distributed themselves to any extent. This has been a disappointment, as observations in Australia and Fiji led us to judge that it would increase and spread without much difficulty.

In our cages, where climatic conditions are quite natural, *Cyrtorhinus* increases very rapidly, although the egg-parasite of the leafhopper *(Paranagrus optabilis)* is quite numerous. This indicates that it is neither climatic conditions nor the egg-parasite that is inimical to it. In going through the cane fields and observing the various species of insects which might attack *Cyrtorhinus* in the young and adult stages, our attention is soon attracted to the "Kissing bug," *Zelus renardii.* This insect is described and figured in Entomological

Bulletin No. 1 (1905), part 7, page 232, plate XVI, figures 1, 2 and 3, under the name of *Zelus peregrinus*.

When leafhoppers were very numerous it was considered as beneficial, as it attacked them, but it was also recognized as doing harm by attacking lady-bugs and other beneficial insects.

During 1919–1920 a little lace-wing fly from Australia *(Micromus vinaceus)*, which feeds on Aphis, was liberated in hundreds in some of the fields where the *Cyrtorhinus* have been liberated, but they all eventually disappeared. *Zelus* was found to prey upon them.

It thus appears that the evidence for and against *Zelus* in our cane fields is divided, but gradually I have come to the decision that we would be better without it, or in much lesser numbers.

Zelus renardii is a Californian insect which found its way into Honolulu previous to 1897 and has gradually spread over the whole of the archipelago.

In California there are five species of this genus, none of which ever become so plentiful as *Z. renardii* does in Hawaii. That they are kept in check by insect parasites is the most natural conclusion, and egg-parasites are the most probable, although I know of no parasites being reported from them. It may be worth our while to make inquiries along this line and to experiment with any parasites found to occur in California.

Present Investigations of the U. S. Bureau of Soils.

By W. T. McGeorge.

It will be remembered that some years ago the Bureau of Soils created quite a stir in soil science, fertilizer, and plant food investigations on its presentation, through the channels of its own bulletins and the columns of the scientific press, of the toxin theory of plant excretions and the claim, based upon experimental data, that the soil solution was not increased by the addition of mineral fertilizers to the soil. In other words that the concentration of the soil solution was a constant.

While these theories have been more or less modified, their effect upon the trend of soil investigations has been of unquestionable value in that it has created more diversified lines of investigation. Undoubtedly, up to this period, it was assumed, too generally, that fertilizer applications acted solely as an additional source of plant food. While certain of this work has been transferred from the Bureau of Soils to the Bureau of Plant Industry, it is nevertheless of interest to note the nature of the activities at present occupying the interest of this Bureau as covered in their recent annual report.

Of their chemical investigations two lines stand out prominently: 1. Anticipating the limitations of the regular chemical analysis of soils they have

sought other means of ascertaining the composition of the soil. Particularly the actual crystalline form of the soil constituents. They have treated soils in one ton lots. Results thus far indicate that the salts occurring in the soil solution are of the same general type as the Strassfurt deposits in Germany and of other deposits formed by the evaporation of inland lakes. In view of the fact that the soil is originally the source of these deposits, in that they have been formed from the drainage and run-off water, their conclusion seems justified. Sufficient progress has been made to show that the different soil types, however, support salts of varying composition in their soil solution. Additional variation results from the use of fertilizers, temperature, and other factors.

2. In working upon these large lots of soil they were able to isolate appreciable amounts of colloidal material or ultra-clay. This substance appeared to be a silicate of aluminum with some iron and traces of magnesium, calcium, potassium, and sodium, probably absorbed. It is upon this substance that the soil depends for its plasticity, as on separating it from the soil it loses its plastic properties. Ten per cent of this substance mixed with sand will dry into briquettes with a crushing strength greater than an equal amount of Portland cement. Yet on placing the briquettes in water they completely disintegrate. This colloidal material was found to possess a very high absorbing power and in a dry state will absorb as much ammonia gas as will charcoal.

The significance of the above to local conditions is very apparent. In the wide variation of our soil types, fertilizer applications, altitude, rainfall, temperature, and other climatic factors, there probably exists a corresponding variation in the composition of the soil solution, and especially the ratio between the elements dissolved therein. What relation this may have to variation in the yield of sugar throughout the islands, or even on the same plantation, can as yet only be conjectured. Regarding the isolation of the colloidal substance conducive of plasticity, attention has been frequently called to the high iron and alumina content of Hawaiian soils. Also the excessive plasticity imparted to local soils by the presence of these elements in amounts many times in excess of that present in mainland soils. The ratio between these two elements varies considerably and it has been noticed that a higher alumina content is usually accompanied by a more colloidal soil structure. It is to this property that we must ascribe the high fixing power of Hawaiian soils. The absence of any harmful results from the continual heavy application of commercial fertilizers in the islands is probably closely related to the presence of this plastic substance.

Another point of local interest in this report is that covering the use of the so-called concentrated fertilizers, such as ammonium nitrate and ammonium phosphate. The effect of cyanamid in mixed fertilizers when it was first introduced to the trade is still fresh in our memory. They therefore advise careful investigation of the properties of these materials before adopting their use. Theoretically and economically they are admirably suited for use as fertilizers. The saving in transportation to isolated localities is worthy of serious consideration.

They advise the following lines of study: 1. The chemical and physical properties of the compounds and the mixtures it is proposed to use in mixed

fertilizers; 2. the compatibility of these compounds in mixtures; 3. limits in which they may be mixed without alteration in composition; 4. properties which interfere with their storage, handling, and transportation; 5. methods for obviating these properties; 6. suitable methods of application.

The supply of fertilizing materials of this nature is of course partly dependent upon the attitude of Congress toward the maintenance of the several large plants constructed as a war measure for the manufacture of nitrogen compounds from the air and of the commercial interests towards the new process proposed by the Bureau of Soils for the manufacture of phosphoric acid by volatilization in the electric furnace. A plentiful supply of basic ammonia is imperative if this substance is to be adopted as a neutralizing agent for the phosphoric and nitric acids supplied by the above processes.

Top-Rot of Cane and Lightning Injury.

By C. W. Carpenter.

The top-rot disease of cane is, as its name implies, a rotting of the top and growing point of the cane stalk. From time to time we have specimens of top-rot sent in for examination, and it has been the custom, in the absence of proof as to the cause of the trouble, to assume that this was in every case infectious top-rot. Since a serious disease of this nature has been reported locally as well as in other countries, we have recommended that where top-rot sets in, all diseased cane be at once cut and burned as a precautionary measure.

It is the purpose of this paper to record certain observations on top-rot of cane as a result of lightning injury. During the past two years specimens of cane showing top-rot symptoms have been received and examined, and several spots of cane in the field affected with an obscure trouble have been investigated. Nothing definite has been seen indicating that this top-rot is infectious in nature. Observations have been made by various members of our staff, as well as by plantation men, indicating that the top-rot in all these cases is a result of lightning striking in the cane field. The rot does not spread beyond the area originally injured, though there is a suggestion of spreading, since the most seriously injured cane in the middle of the spot rots first. The evidence supports the view that the cane tops were rotting as a natural sequel to death from some external factor.

In 1914 Jones and Gilbert[1] called the attention of pathologists to the subject of lightning injury to herbaceous plants, particularly cotton and potato. In a later paper these writers[2] state that there have been several reports of light-

[1] Jones, L. R., and Gilbert, W. W. Lightning injury to cotton and potato plants (Abstract). *In* Phytopath., Vol. IV, p. 406. 1914. Two plates.

[2] Phytopath. Vol. VIII, p. 270–282.

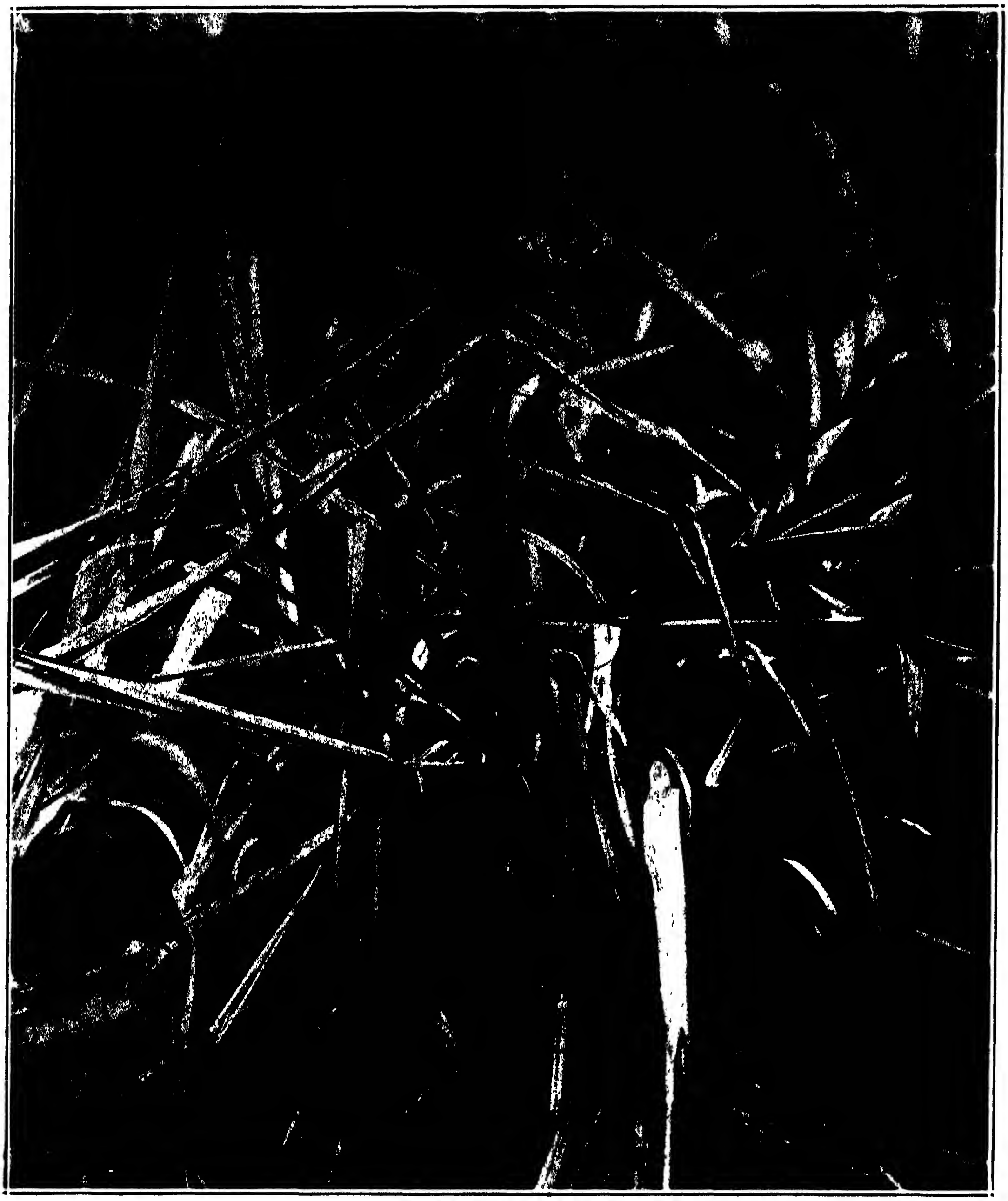


Fig. 1. Lightning injury of cane. Note the shredded top leaves of the stick in the center.

ning injury in each of the following crops: cotton, potato, tobacco, and sugar beets; and single reports for kale, alfalfa, ginseng, onion, tomato, cucumber, Indian corn, and sugar cane. In the case of the last two crops the evidence is noted as less conclusive. Concerning the types of injury we may quote Jones and Gilbert at some length (l. c. p. 281):

"In respect to description of the injuries, while there is some variation in details, there is a surprising amount of likeness as to the general characters. Certain things have been reported upon enough to merit review. In general the killed areas vary from 10 to 30 feet in diameter and are roughly circular in outline. Where much larger areas or irregular extensions have been noted, it has been suggested that the distribution of the damage was probably associated with the presence of surface water. As suggested in our earlier article it seems possible, and at least justifiable as a working theory, that the greatest damage results when the lightning stroke occurs soon after the rain begins. According to this theory the drier soil below the surface would then favor the wider diffusion of the shock through the recently wet or flooded surface layer. In general the killed areas are sharply delimited, although the margins are somewhat ragged and there is a narrow zone of partially killed or weakened plants.

"In most cases there is little or no evidence of mechanical disturbance at the surface of the soil, although certain observers make definite report of a small, crater-like depression at the center of the disturbed area. Probably this is not a constant feature, and in any case the amount of dislocated soil is so small that the accompanying rain would generally obscure or obliterate the evidence. With herbaceous plants there seems little mechanical splitting or tearing of the injured tissues. It seems possible that in the few cases where this is reported (potato, sugar cane) it may represent a splitting due to the sharp bending and the shrinkage of the stems after injury rather than an actual rending by the electric discharge."

Jones and Gilbert (p. 282) explain the lightning injury phenomena in the following language:

"When an electric storm breaks suddenly following a period of dry weather, and the first rain wets the top soil, there remains a layer of dry earth between this wet surface and the moist soil underneath which is a poor conductor of electricity. When the lightning strikes the wet surface soil it disperses in all directions horizontally and then downward, following lines of least resistance. The plant stems and roots with their abundant water content are better conductors than the layer of dry soil just mentioned and so the electrical current passes through them. The tissues may thus be variously injured or killed, depending upon the amount of current passing through them. The strength of the current, of course, diminishes the farther it gets from the center of the affected spot, and consequently the lessened injury at the margins of the area. In some cases apparently the discharge may be broken and strike in several spots near together."

Fig. 2. Part of a stick struck in the middle. The top was not visibly affected, but the stick was neatly stripped of leaves below the injury.

In cane, as we have observed the evidence, the injury appears to be direct rather than diffused through the wet soil killing the roots. The diffusion appears on the contrary to be over the wet surface of the leaves, the dry cane trash below serving as a non-conductor in some degree.

Stevenson [1] records an observation of lightning-injured cane, a type of injury which he says is apparently rare. The area was circular and about a rod in diameter, sharply set off from the surrounding mature cane. In the affected area only a few dead stalks remained, some broken off a few feet above the ground. There had been no growth of new shoots, and the stools were dead. Charred bits of cane trash were found which, combined with other evidence, suggested lightning as the cause. Stevenson stated that no other source of fire could have destroyed green cane so completely, especially the underground portions of the stools. He does not mention top-rot in this connection, and this symptom, if present at first, was doubtless not existent at the time he saw the spot.

The symptoms of the top-rot disease of cane are outlined below. It does not seem necessary to take up the finer details of description, since this has already been done in Pathological Circular 5, certain paragraphs of which are quoted below.

In the disease as it has come to our attention, the top of the spindle is rotted and soft at its base, the top being readily pulled out. The leaves are at first tinged purple on the exposed surfaces and somewhat lacking in turgor. They later dry up, the top joints shrink markedly and the soft, ill-smelling rot proceeds downward, accompanied by the usual discoloration of fermenting cane sticks. It is a top-rot and nothing as to its cause in Hawaii has been determined, though numerous suspected organisms have been investigated.

That the disease as described by Cobb had much in common with what we are now discussing is shown by a few paragraphs quoted from his paper:

> "The attacks are more likely to come to the attention of the grower after rainy spells than at any other time,

[1] Stevenson, John A. Lightning injury to cane. *In* Phytopath. Vol. VII, p. 317–318. One plate. 1917.

as such weather is more favorable to this disease. In pronounced cases the plants over considerable areas, which may up to that time have done well, will lose color at the top and change in appearance rapidly, the leaves becoming yellowish or reddish, then ashen. The odor of the disease begins to be perceptible at about this time; that is, at the time when the tops are no longer green. On taking hold of the top of a diseased stalk, it will break off and easily pull loose, and at the broken part the nostril will detect, if it has not already done so, the pig-sty odor that is characteristic of the disease. This is so pronounced as to be noticeable in the field in calm weather at some little distance from the diseased plants. Stalks of cane several months old often retain their normal appearance at the base even after the tops have died, but it is not long before this part of the cane becomes diseased also. Ultimately the whole stalk dies. Outwardly the most striking appearances on the stalk are the marked shrinkage in the upper internodes. This is so pronounced that in the case of the upper and most sappy internodes the surface falls in, so that in places the curvature of the surface is reversed, becoming concave instead of convex. All this may occur on the stalk without its losing its normal color.

"If one of the stalks be split in halves from end to end, some of the most pronounced lesions of the disease are brought to view. It will be at once noted that the most pronounced symptoms are located at the top of the stalk, fully justifying the name *Top-Rot*. Below the base of the arrow, that is, at the top of the stalk where the younger leaves originate, and at the point where, as it has been already noted, the top easily pulls loose, is a cavity in the stalk. If the disease is well advanced this cavity is filled with a brownish or yellowish, offensive looking, and even more offensive smelling, slime. There may be more than one of these cavities, but there is one, coincident with the base of the upper group of shortest internodes, that is somewhat different from all the others, supposing any others to be present. This cavity may not be the largest, but it is that in which there is usually the largest amount of slime in the most offensive state. * * * * * * *

"There is no evidence to show that *Top-Rot* is easily spread. It is uncommon for it to affect large areas, and, so far as can be judged at present, it is seldom destructive in Hawaii except after unfavorable weather—that is, long continued rain."

In January, 1920, Mr. R. S. Thurston called attention in his notes to several patches of diseased cane on Kauai in the following language:

"In field 36 there is an area of about 1/20 acre in which the Yellow Caledonia cane has turned yellow and the tops of the larger sticks have rotted. In some cases just the center has rotted out, while the older leaves look normal. In other cases the older leaves have a dark reddish purple hue, near their tips, this color extending for quite a distance down the midribs. I have never seen anything like it before.

"Mr. Broadbent showed me a spot here on Grove Farm where the cane is diseased the same as at Kilauea. In the past few days six such spots have been discovered here. In at least four of the cases a peculiar circumstance is that at about the center of these spots there is a hole in the ground about 12 to 18 inches in diameter and 6 inches deep. And near this hole all the leaves are covered with dirt, the dirt having lodged between the leaf blade and the stalk. In these spots the dead centers and purple leaves are present, the same as at Kilauea. This would seem to indicate that these spots were struck by lightning."

On April 29, 1920, Mr. W. L. S. Williams discusses in his notes similar diseased areas on the Island of Hawaii, as follows:

"Top-Rot epidemic. Outbreaks of top-rot are now reported from Papaaloa and I have seen one at Hakalau which appears to be just starting. I am beginning to incline to the theory that these centers of infection are due to lightning in the storm of March 29–30. For one thing the cane leaves appear burned and discolored, aside from the spots and blotches caused by the disease. In the second place I noticed at Pepeekeo in a field where the trash had been burned off that some large suckers that had been in contact with the flames bore the same markings and that the centers had decayed similarly with the centers of canes affected with top-rot. The characteristic odor was also present. * * * * * * The disease might have got its start in the canes when in this weakened condition, or it may be that the fermenting of burned cane causes an odor that is similar to the top-rot odor. This does not explain the apparent ability of the disease to spread to healthy canes though."

The writer visited some of these diseased areas on Hawaii April 29 to May 2, 1920. At Papaaloa, in Field 8 of the Laupahoehoe Sugar Company, second ratoon, D 1135, five to six feet high, at an elevation of 1250 feet, a spot of sick cane about 50 feet in diameter was seen. The following is extracted from a trip report at the time:

"The affected cane could be remarked at considerable distance, owing to the peculiar seared appearance, in contrast to the healthy cane surrounding it.

"On closer examination it was found that the leaves of many of the plants were somewhat lighter colored than normal and with a varying portion of the tips or mid portion of the exposed surface tinged a peculiar mottled purple color. This color in general was most prevalent in the plants near the center of the affected patch, and here, too, a number of 'top-rot' plants were found. The central portion of the plant was readily removable, the spindle being a purulent rotting mass with a vile odor. In general the 'top-rot' plants were in the central part of the diseased spot. The top internodes did not show the shrinkage characteristic of infectious top-rot. Outside of this area or in the

Fig. 3. This stick was struck at the top and the leaf-sheaths below the mid-portion remained intact before bringing to the laboratory. The bolt jumped to the middle part of the stick shown in Fig. 2.

border zone the plants showed a grading off in the purpling effect. Plants shorter than the normal, often as if by protection of the larger plants, escaped entirely. Those plants not showing the top-rot appear to be growing away from the disease, as the central leaves are healthy. It is the fifth leaf, etc., from the top which shows the purpling effect. The significant thing of interest to me in this case is that we have as an associated symptom with 'top-rot' a purple coloration of the foliage more or less extensive on those surfaces which must have been the uppermost exposed surfaces of the top leaves a few weeks ago.

"Two more similar spots of cane were pointed out to me at Papaaloa, one in mature Demerara 1135 in Field 9 and one in Field 3 in Yellow Tip cane. The latter does not show as marked purpling nor as extensive disturbance as the others mentioned. There was very little top-rot in either of the two latter.

"The spots were first noticed about a month ago and it is recalled that there was a severe electrical storm about that time. The symptoms of the disease and the relation to the storm recall the very similar, if not identical, trouble at Kilauea and Grove Farm Plantation in January. The Demerara at Kilauea is said to have grown away from the trouble."

The following impressions are quoted from a report dated June 28, 1920, in answer to an inquiry:

Fig. 4. Cane stick with shredded top. This stick was suffering from top-rot. Note the shrunken internodes.

"We have records of cases of top-rot in which the disease spread over considerable areas, and other cases where the affected cane was in small spots similar to those recently found at Honomu. The whole question of top-rot disease is somewhat confusing, since we know so little of its cause, the history of individual outbreaks being rather conflicting. A continuous study is not possible, owing to the lack of material for observation except at rare intervals and then only for a short period.

"In the recent outbreak in small spots at Honomu, Laupahoehoe, Olaa, etc., considerable evidence was obtained to support the theory that the tops of the cane were injured by some external factor and that the rot was but the natural decomposition of the dead tops. Lightning is a plausible factor which could account for this injury in circular areas and with the graduated relative amounts of injury from the center of the patch to the periphery, the taller plants being in general most affected, while leaves lower down escaped. Conceivably if the cane was struck by lightning when the leaves were wet, the effect would diffuse over the wet and exposed leaves (tallest plants, leaf tips, etc.) until the charge was so diffused as to be harmless. The charge might be insufficient to travel down the dry stalks and tear them out, thus leaving tangible evidence of the cause of the disturbance.

"In some similar cases of top-rot from Kauai, a hole in the ground several inches in diameter was noticed near the center of the spots, and soil deposited in the leaf bases was remarked. If lightning strikes cane, and we have no doubt it does occasionally, it is reasonable to believe that in some cases the charge is stronger than in others; the conditions as to electrical conductivity are variable, and thus the effect is diverse.

"In the material at Honomu most of the described symptoms of infectious top-rot were present, yet since it did not spread, we must assume that the conditions favorable to infectious top-rot were not long prevailing, or the cases in question were not infectious in nature, but rather rotting of the tops as a result of death from some undetermined cause. Where the cane is very dry and a sudden shower wets the top leaves, followed by lightning discharge, it likewise seems possible to the writer that the effect might be so diffused over the tops as to lead to the assumption later that the effect (disease) was spreading."

On February 5, 1921, further specimens of top-rot were received from the Hilo Sugar Company. The lower portion of the top-rot stalk received had a distinct cooked appearance. Late in March, 1921, our attention was called to three top-rot spots of cane at Ewa Plantation by Mr. W. P. Alexander. The cane is H 109, second ratoons, nine months old. On February 18 there was a severe electrical storm, the rainfall during several hours having been 1.2 inches at the mill. The diseased spots were not found until the irrigation gang made the next round.

These spots were not far apart, the first being about forty feet in diameter and the other two much smaller. In the larger spot there are about forty sticks showing top-rot, in the immediate vicinity of a stool one stick of which shows the top leaves shredded and the lower leaves and sheaths stripped neatly (Fig. 1). In another area the bolt shredded the top of one stick, and apparently jumped to an adjacent curved stick, as the leaves were stripped only part way down, and the adjacent stick had a rot lesion about 4 inches long on the side nearest the first mentioned stick. The first stick was stripped down to the point of departure, while the second stick was still healthy looking at the top but was stripped below the lesion. (Figs. 2 and 3.)

It would be purely fortuitous to observe lightning striking in cane fields and to definitely locate the spots where it hit. The fact that top-rot, in the experience of Cobb and others in Hawaii, follows rainy weather is possibly susceptible of deductions other than that wet weather favors the disease, as has generally been assumed. It is hoped that this note on top-rot and lightning injury will serve as a nucleus around which to gather additional data.

The Fig Wasp in Its Relation to the Development of Fertile Seed in the Moreton Bay Fig.

By C. E. Pemberton.

Summary.

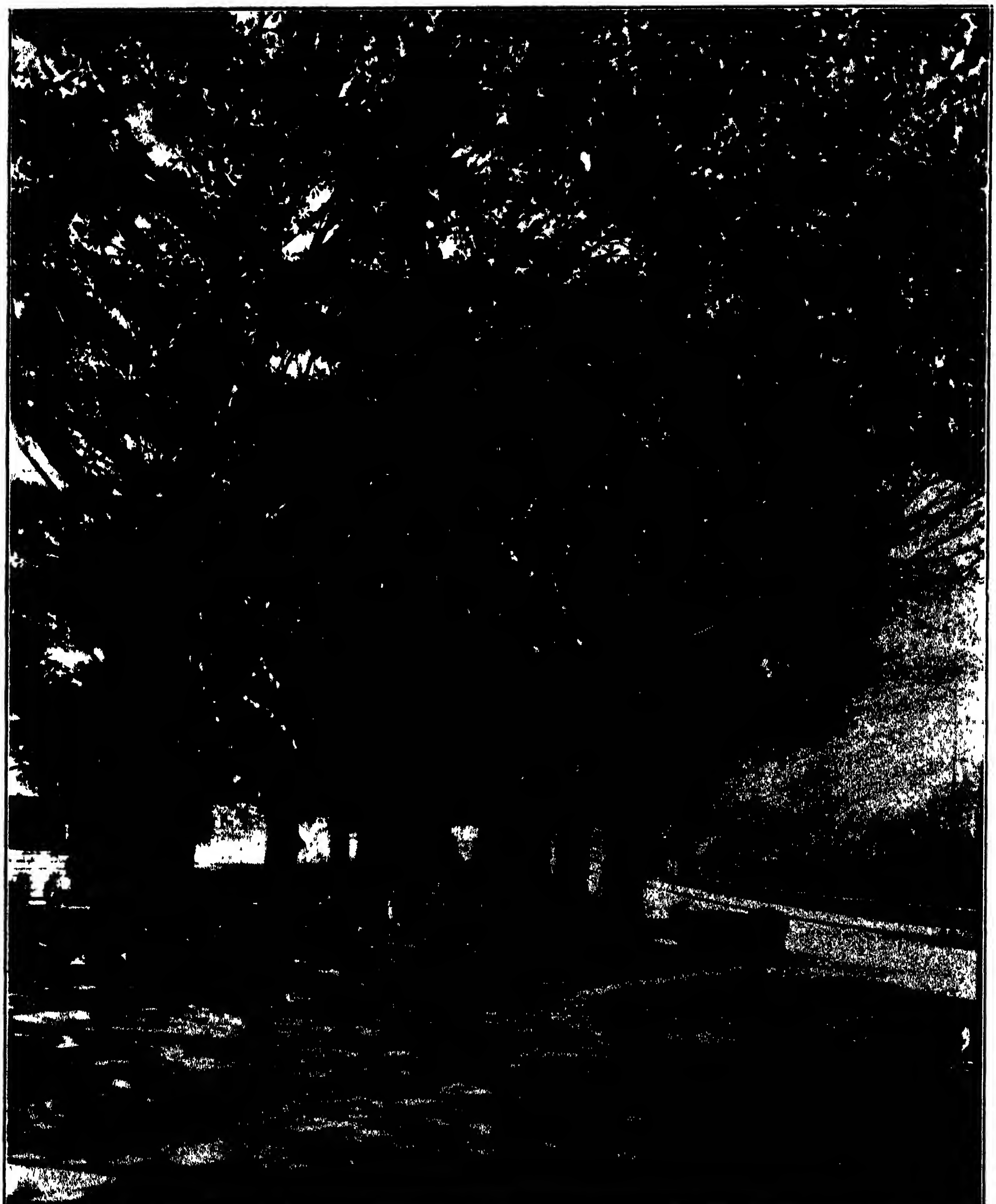
The presence of the fig wasp is necessary for the natural development of the Moreton Bay fig and for the development of seeds as the sequence of the development of the male and female flowers in the fig prevents self pollination, and unless the female flowers are pollinated when the figs are young the figs fall off so that the male flowers do not come to maturity.

In connection with the propagation of the Australian fig, *Ficus macrophylla,* for reforestation purposes in the Hawaiian Islands, a study has been undertaken in Australia of the factors essential to the production of fertile seed of this tree. The following will cover the results of this work, indicating the vital part played by a certain insect in the perpetuity of the tree, showing in some detail its remarkable habits, and establishing proof of the absolute need for the introduction of this particular insect into Hawaii, before the tree can be permanently added to the forests and increase naturally in the future.

The most eminent botanists of modern times fully recognize the important part played by insects in the reproduction of many plants. The assertion of Eisen, an authority on fig culture, that "Nearly every flower we see in the field, and certainly every bright-colored flower, requires the visit of some insect, in order that its stigma may be fertilized by the pollen, which adhered to the insect, when it left the last flower visited," is amply confirmed by much elaborate work on insects in their relation to flower-pollination, by such prominent scientists as Kölreuther, Sprengel, Knight, Darwin, Hildebrand, Asa Gray, Fritz Müller, Hermann Müller, Trelease, Henslow, Knuth, Delpino, and a long list of others, totalling over 3,000 works relating to the subject. The fact is well established that no plants with colored or showy flowers existed before insects first appeared on the earth, and the development of their flower-parts following the occurrence of insects, has been very remarkable in the arrangments to prevent self-pollination and to attract insects to ensure cross-pollination.

Apart from the grasses, conifers, and many other plants completely lacking in colored, odorous or attractive flowers, the great bulk of the other plants now rely absolutely upon certain insects for the continuance of their virility or actual existence, through the cross-pollinating work of such insects. Plants of the genus *Ficus* (all species of figs) are included in this group. Their special flower adaptations directed to prevent self-fertilization and aid certain insects in fulfilling their mission of cross-pollination for the figs are most extraordinary.

Entomologists and botanists have long recognized the presence of certain peculiar wasps in figs of various sorts and much speculation has followed re-



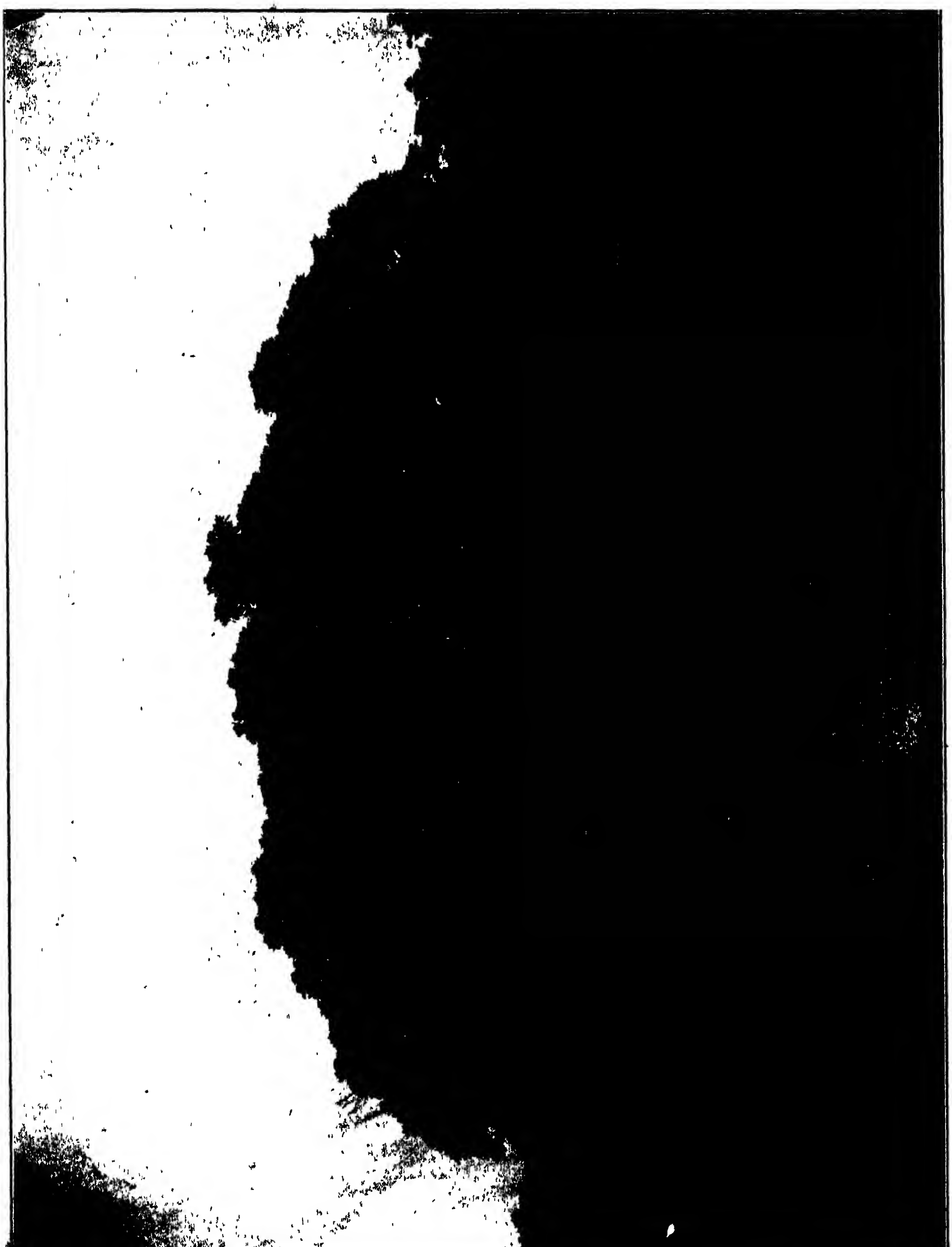
Avenue of Moreton Bay figs (*Ficus macrophylla*) in the Domain, Sydney.

garding their importance to the fig in its development and in the production of fertile seed. As an example of their early recognition, Sir J. D. Hooker, as early as 1890, in the "Flora of British India," in an introductory discussion of the genus *Ficus,* states that "The gall-flowers are like the female but perfect no seed, their style is short, often dilated above, and the ovary occupied by the pupa of a Hymenopterous insect." This statement holds perfectly true to-day.

The Smyrna fig of commerce, grown extensively in Syria and Asia Minor, will develop to edibility only through the agency of one of these wasps. This fact has been known for hundreds of years. A simple horticultural operation designed to keep an abundance of these wasps present in the orchards where the Smyrna fig is grown has proven absolutely necessary, otherwise the crop fails. This process has been carried out in Greece since very ancient times. Aristotle left written accounts of the wasp and its importance. Theophrastus wrote extensively on the subject, with a fair understanding, and the elder Pliny, the great Roman naturalist of centuries ago, left important records on the knowledge the ancients had of it. Linnaeus, in 1749, wrote a careful account of the wasp and its habits. Smyrna fig trees were first imported into California in 1880 and extensively planted out. Though the trees grew well no figs were secured after many years of futile effort. Ultimately, through the co-operation of United States entomologists, living fig-wasps from Asia Minor, of the species particularly occurring in the Smyrna fig and its related, wild, so-called Caprifig, were imported into California and established in a Smyrna fig orchard of a prominent California fruit grower. Caprifigs were also growing in his orchard. In 1900 the first crop was picked. Sixty tons of splendid Smyrna-figs were taken from this orchard, and this was only after the thorough establishment of the wasp. Not a single fig matured during the many years prior to the introduction of the insect.

In a propagation of the Moreton Bay fig in Hawaii, the experience will be necessarily similar to that in California with the Smyrna fig. It can develop fruit and reproduce only through the aid of its own particular fig-wasp, which occurs in the figs of this tree in certain parts of Australia, and it is absolutely essential that this wasp be established in Moreton Bay fig trees in Hawaii before they will ever produce fertile seed. The following account should be sufficient to prove this point.

Three main types of flowers occur in figs. These are the male, female, and gall flowers. Flowers known as neuter are also said occasionally to occur. Each receptacle or fig bears on its inner wall great numbers of these flowers. Some species of *Ficus* bear figs on one tree in which only male and gall flowers are present, and on another tree, figs containing only female or seed-forming flowers. In other species both male and female flowers occur on the same tree but in separate figs; the gall flowers always occurring in the same fig with the male flowers. Still other species of *Ficus* bear all three kinds of flowers in every fig produced. The Moreton Bay fig is of the latter type. Here (Figure 1) each fig contains an abundance of male or pollen-bearing flowers, true pistillate or female flowers in which the seed develops, and certain imperfect female flow-



Ficus macrophylla in the Botanic Garden, Sydney.

ers known as gall flowers which exist and function solely to hold and nourish the developing fig-wasps.

In Figure 2 a much enlarged view is shown of the three kinds of flowers present in every immature Moreton Bay fig. The perianth of each has been removed to show the relative size and shape of each, all being drawn to the same scale. The flowers have this appearance when the fig is small and the basal bracts surrounding it are just unfolding, as shown in Figures 3, 4, and 5. The fig is then about one-half inch in diameter, with considerable variation and is somewhat hollow. When a fig-wasp enters, there is plenty of room for it to move about freely in order to lay its eggs. All three types of flowers are well distributed. The male flowers are not confined to any particular part of the fig as in many other species of *Ficus*.

Figure 2A shows the normal female flowers, destined to form a fertile seed. At this time, while the fig is small and young and the basal bracts shown in Figures 4, 5, and 6 are just opening, the stigma of this flower is widely expanded, pale white in color, erect and fully ready to receive any pollen which may get on to it from a fig-wasp when it comes into the fruit to lay its eggs. A few weeks later this stigma withers, the style supporting it droops, both assume a dead, brownish color and any pollen then reaching the stigma is powerless to effect a fertilization of the ovary. Figure 8 shows the appearance of the same flower, after being properly pollinated and matured to a perfect seed. Figure 2B shows the gall-flower as it normally appears in a young fig, mixed in with the other flowers. There are a hundred or more of these in each fig. In this type of flower and in no other, the fig-wasp lays its eggs as explained below. This flower, though a pistillate or female one, is destined to produce a fig-wasp and not a seed, if an egg is deposited into it at the proper time. The stigma appears quite similar to that of the true female flower both as to size and shape and in the apparent possession of well-developed receptive glands. The style, however, is normally shorter than that of the female flower, as shown in the figures. There is considerable variation in this. Gall-flowers have been found with fairly long styles. The short style of the gall-flower enables the female wasp to place its egg properly within the ovary below. The male flowers, in which the pollen develops, shown in Figure 2C, are very immature in any given fig, at the time the female flowers in the same fig (Figure 2A) are just ready to receive the pollen. The female flower, as just explained, is ready for the pollen and must have it then or never. This is when the fig is small and the basal bracts are just opening. All of the male flowers in it then are very immature and will not dehisce or rupture and scatter pollen until the fig is ripe, several weeks later. Hence the need for some agency to bring ripe pollen into this tightly sealed-up. undeveloped fig, from some ripe fig on the same or another similar tree. Here the fig-wasp plays its part.

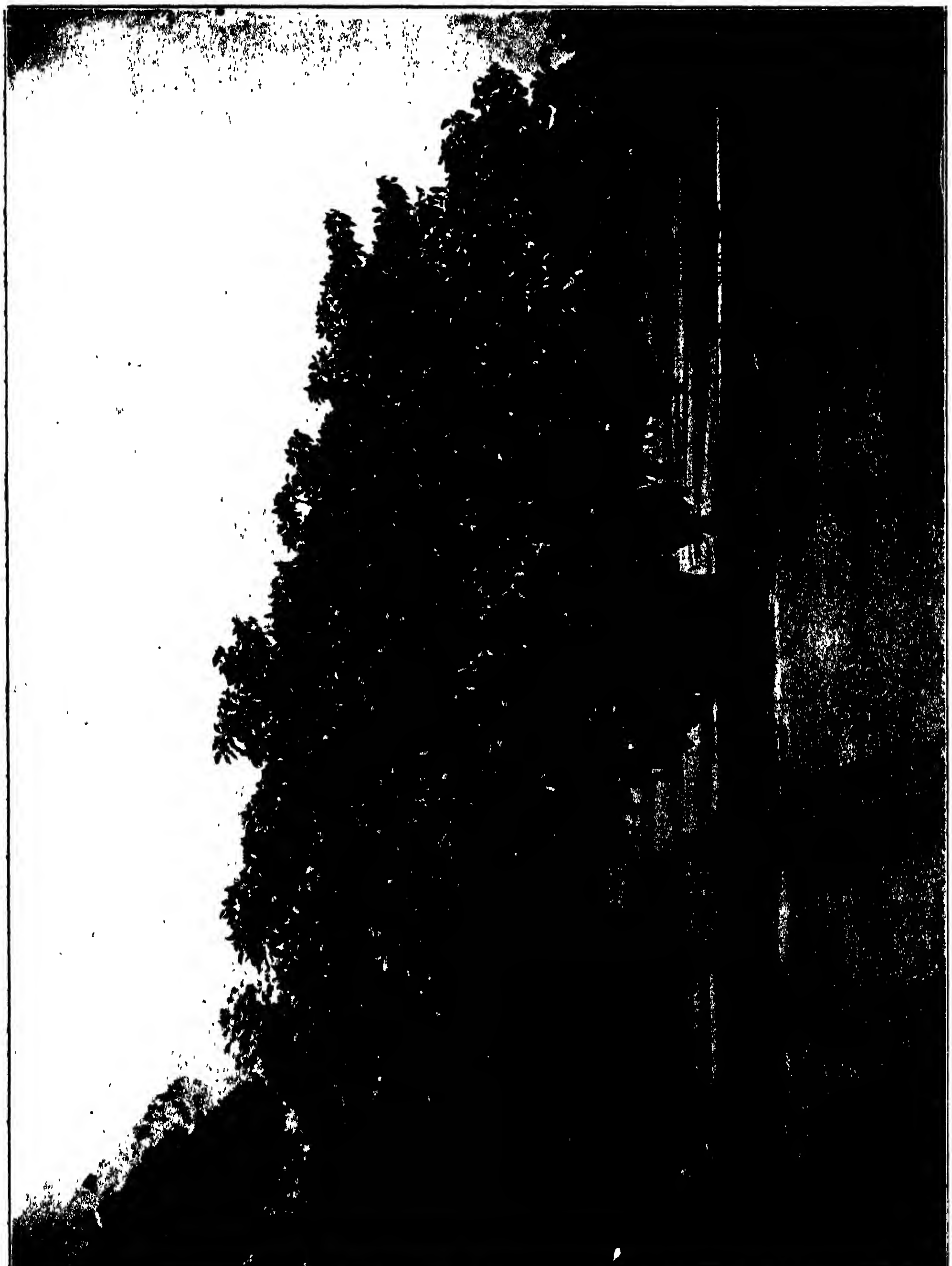
Though fig-wasps of several species are present in the Botanic Gardens in Sydney, Australia, where the present investigations were carried out, only one species, *Pleistodontes froggatti* Mayr, was bred from the Moreton Bay fig. Mr. W. W. Froggatt records another species, *P. imperialis* Saund., though it is apparently rare.

Ficus macrophylla in the Botanic Garden, Sydney.

The common *Pleistodontes* commence boring out of mature figs, as shown in Figure 7, about a week before the fruit falls to the ground, with variations depending upon wind, rain, and temperature. The figs, which are light green in color, are just beginning to soften, assuming a yellowish tinge, when the wasps emerge. They then quickly change to red, purple, and finally dark purple, become very soft and fall to the ground. Only the female wasps leave the figs. They easily emerge by boring minute holes through the wall of the fig at any convenient place. See Figure 7. When from one to six holes have usually been made, through the emergence of a similar number of females, the others hatching within the fig seek an outlet through these holes. Hence only about one to six perforations appear on a fig after the females have hatched out and these suffice for the liberation of often eighty or ninety wasps. On December 17–18, 1920, a total of ninety-three females emerged from a single fig under observation. At just the particular time when the wasps are hatching from the fig, the male flowers in the same fruit are reaching maturity, the anthers or pollen sacs are rupturing freely, by a single, longitudinal slit, and a vast quantity of minute, white pollen grains are scattered throughout the interior. It is remarkable that the pollen should thus be naturally liberated within the fig at just the time the wasps are hatching out. This, however, is invariably the case. Every wasp becomes covered with pollen, without exception. Some emerge literally white with it.

The female will fly readily. Her immediate aim upon leaving the fig and partially cleansing herself of excess pollen, is to locate a small fig with the enveloping bracts just opening to expose the tip. She quickly flies up and away. She is capable of an extended flight, through the help of the wind. She may be carried a long distance from the tree from which she hatched. Individual females have frequently been taken, very much alive, on the roof of a hotel in Sydney, well removed from the Botanic Gardens or any fig trees.

Instinctively a fig of the proper size is soon found and the female commences an elaborate operation of boring into it at its apex or end, just where a series of eight to twelve imbricated, elongate, turned-in scales close the end. A female never attempts to enter a fig at any place but this. The area of operation is very small, hardly exceeding more than a sixteenth of an inch in diameter. If the bracts covering the fig have not opened sufficiently to expose this spot, as shown in Figure 6, the wasps can frequently be seen moving about over the fig near the apex, apparently awaiting the unfolding of this leaf-like fig-covering. As soon as the tip of the fig is exposed, one or more wasps usually find it and commence boring in. As many as fifteen females have been counted, all trying to insert their heads into the fig at exactly the same spot. Many never enter, are crowded out by the others, and only get the head partially imbedded. Most young figs thus soon have one or more dead wasps at the tip, with the bodies projecting from the fig and firmly held by the head, which is wedged in a fraction of an inch. From one to six, or sometimes more, usually gain entrance, however, into most of the young figs. A wasp will not enter such a fig if a hole has been previously made for it at the apex. A fine needle-hole made at the exact spot desired by the wasp for entrance was several times



Ficus macrophylla in the Botanic Garden, Sydney.

made in young figs, and large numbers of freshly-hatched females then placed on the fig. None were ever seen to enter this hole. They began gnawing around the edges. The instinct to enter by force, only after a laborious and often fatal effort, through the sticky, tough, fig-skin, is apparently as much a part of the necessary life-function of this wasp as that of laying eggs. No food seems to be taken while boring into the fruit. The alimentary canal of several has been carefully examined just after the individuals had passed into the fig. Nothing could be found but the minute, spherical masses of oil-like globules which are present in newly-hatched females taken before entrance into a fig.

The structure of the head of the female is remarkably adapted for facilitating the difficult entrance into a fig. At the time the wasp works into it, the wall of the fig is comparatively strong and hard. The tissues are full of the thick, milky sap which flows at the slightest scratch. The entire process of gaining entrance is a slow one, though the actual distance through which the insect cuts is hardly greater than the length of its head. As above stated, many never succeed in entering and die in the attempt. This sometimes occurs even when there is no crowding about the fig-apex. Several individuals have been kept under observation from the time they commenced boring into the fig until the tip of the body and the posterior pair of legs had finally disappeared. The time required in these cases varied from one hour and twenty-five minutes to one hour and forty minutes. The wasp first moves about over the end of the fig, attracted probably to the desired spot by a sense of smell. She finally applies the tip of the head against the fig and becomes perfectly motionless. The two first antennal segments are brought close together, are somewhat pointed and project slightly in front of the tip of the head, just beyond the mandibles. These are pressed against the fig, the other joints extending upwards and in front of the head. The two strong, hook-like mandibles are then raised and lowered slowly. They do not operate laterally. The motion is more forward and backward. In raising them the tips are pushed forward. In lowering them, they are forced against the tissue. This can be better understood after an examination of Figures 12, 13, 14, and 15. It is somewhat of a forward-reaching movement to fix the tips into the tissue in front. Then in lowering them the whole body is drawn forward an imperceptible distance. The remarkable so-called "mandibular appendages," attached to the bases of the mandibles and extending ventrally backwards the length of the head, are so beautifully constructed and situated that each movement of the mandibles forward draws the appendages forward also, and the saw-like serrations and spines with which they are totally covered, as shown in Figures 12, 13, 14, and 15, completely prevent the head from slipping back. Every forward movement of the head, gained by ever-so-slight a penetration by the mandibles, is insured against slipping back by these barb-like appendages. As the wasp slowly gains further entrance into the fig, the appendages may be expanded laterally, as shown in Figure 13, which doubly prevents any but a forward movement of the wasp, once it inserts its head slightly into the fig. When first establishing a hold on the surface of the fig the wasp will revolve its body to the right and left with the tip of the head pressed against the fruit and acting as a pivot. The movement is always slow.

After a third or more of the head is into the fig tissue, the entire body becomes raised from the fig and the only portion in contact is that part of the head inserted. The legs and wings then extend backwards in a rigid manner, as shown in Figure 4, remaining almost motionless and utterly useless. As the action of the mandibles and their appendages draws the body further in, the legs are brought into use and are the sole means of pushing the body completely through the aperture after the head has passed entirely into the open interior of the fig. Specially developed claws or spines on the anterior and posterior pairs of legs are present to assist in this operation.

The difficulties encountered by the wasp in piercing the fig-wall invariably result in the loss of the wings and the outer six antennal segments. See Figures 16 and 17. Many hundreds of females have been examined after penetrating into the fig, and the wings and six antennal segments are always missing. The wings usually remain protruding from the end of the fig, glued there by the small amount of sap exuding from the wound made in the fruit where the wasp entered. The broken-off antennal segments are less conspicuous, but can be found in the fig-wall near or at the outer surface just where the wasp entered. No cases have been observed in which the wasp lost any legs or portions thereof in entering a fig. When the wasp is finally into the fruit she resembles that shown in Figure 6, greatly enlarged. Usually more than one wasp gets into each young fig, and often five or six will successfully enter a single fruit. After a few wasps have thus entered, either fresh wasps are unable or have no desire to enter this particular fruit, for no fig has yet been opened in which more wasps had entered than could conveniently move about in the small interior for egg-laying. Yet there are generally more wasps about a tree than are necessary for the proper fertilization of all the figs thereon. Much of the pollen must be brushed from the wasp's body during the short but strenuous trip from the soft, mature fig from which it hatched to the interior of the solid, sticky, milky, young fig, where it has finally arrived to lay its eggs. Many have been removed after reaching the center of a young fig and their bodies carefully examined for pollen grains. Though usually found on some part of the wasp's body, it must be admitted that pollen grains are not frequently numerous; yet sufficient is carried over to secure ample pollination for a great many female flowers in each fig.

When a female has finally reached the interior of a fig, she immediately begins egg-laying. She very energetically searches about over the surface of the flowers with the ovipositor withdrawn from the sheath, forcing the tip into every stigma encountered with the evident intention of finding the stigma of a gall-flower. There is only a moment's pause over each stigma until the desired one is found. Then the ovipositor-blades are run through the stigma, down along the channel of the short style and well into the ovary itself, not in the center, but to one side. The blades are then held in this position while a minute egg, hardly one seventy-fifth of an inch in length, with one end attenuated to a long, drawn-out stalk, passes down between them and is deposited into the base of the flower. The freshly laid egg is shown in Figure 11, very greatly enlarged. The position of the female while ovipositing is shown in Figure 6

and the egg in position is seen in Figure 18. Many ovipositing females have been removed from figs with the flower intact, placed beneath a microscope and observed during the operation. Even under this disturbance the wasp will continue working until the egg has been laid. Under strong lighting, the ovipositor can be seen in position within the tissues of the delicate, transparent gall-flower. Several minutes are usually required to deposit a single egg. Some have been timed for five minutes before the ovipositor was withdrawn. The female continues laying in gall-flowers until death. Her egg-laying capacity is fairly large. The greatest number of well-developed eggs dissected from a single newly hatched female was 149. As her life is very short, the eggs seem all nearly mature when she first hatches out. A single individual is thus capable of placing an egg in nearly every gall-flower in a fig. Sometimes, after ovipositing her eggs, a female attempts to bore out of the side of a fig. She never succeeds in this. Many have been found dead with the head partially imbedded in the inner wall of the fig, but a complete emergence hole has never been seen on a young fig. Females usually remain alive and continue egg-laying in a fig for about two days after first boring in. Sixty-eight individuals were placed upon screened-in, young, untouched figs on December 24th, 26th, and 28th, 1920. Six were still living and trying to oviposit when the figs were opened forty-eight hours later, but they were feeble. All the others had died. The life of an adult is thus very short under normal conditions. Many attempts were made to prolong the life of the adults beyond a few days. None could be made to take sugar and water or honey and water and thus kept alive for long periods, as can easily be done with many Hymenoptera. The longest life of any individual kept under experiment was four days. Of a total of 200 freshly emerged females placed in test-tubes and kept in absolute darkness, twenty-two lived for three days and five held out for four days. Other lots placed in the light and fed various substances all died after two days. As shown below, their life can be best prolonged by subjection to fairly cold temperatures. Most probably, as experienced by Back and Pemberton in fruit-fly refrigeration experiments, the nearer 50° or 51° F. they can be held, the longer their life can be prolonged. Future shipments of different species of fig-wasps from different countries in connection with the propagation of various trees of the genus *Ficus*, will probably find greatest success in the adoption of such a method where it is impracticable to ship the living tree with the wasp.

The fig continues growing rapidly after the wasps have entered it, laid their eggs, died therein, and incidentally brought in the pollen for the female flowers. The interior space wherein the wasps moved about, soon becomes completely filled with the enlarging flowers, of all three types, and the dead wasps become greatly crushed, distorted, and partially dissolved by the thick sap in the fig.

The egg, within the gall-flower, hatches into a small, pale-white, and exceedingly delicate larva, wholly devoid of any striking or readily recognizable characters. The mandibles are only faintly chitinized and not easily found. The length of the egg-stage was not determined. The larva remains within the gall-flower, feeding upon the surrounding tissues, and the flower itself grows

Ficus henneana **in the Botanic Garden, Sydney.**

to more than double its original size, finally assuming the shape shown in Figures 9 and 10, with some variations. The larva matures within the gall-flower and pupates therein. Both male and female pupae have been dissected in quantity from the gall-flowers.

The males hatch out first by gnawing, with strong mandibles, a small hole in the top or side of the gall-flower, creep out and immediately work slowly and clumsily about in the fig searching for other gall-flowers in which female wasps are maturing. The male is wingless, yellowish-brown in color and quite unlike the female in general appearance. It is of the same peculiar type as that of the male of the Smyrna fig-wasp and many described from other figs. The male outlives the female by several days and is much less numerous. When a gall-flower containing a female is found, the male gnaws a hole, usually in the side of the gall, inserts the tip of the abdomen, fertilizes her and then moves away to another flower. The female then works her head through this hole, enlarging it somewhat, as shown in Figures 9 and 10, and emerging into the interior of the fig; then boring immediately through the side at any point or seeking an outlet through some emergence-hole just bored by another escaping female, and thus completely leaving the fig. At this particular time, as previously indicated, the male flowers in the fig have ripened, ruptured, and cast a profusion of pollen throughout the inside. It is thus impossible for the female to escape without being covered with pollen, and she immediately starts in search of young figs, as discussed above.

The time required for the total development of the wasp is necessarily dependent upon temperature and the growth of the fig. The wasp-maturation is completely coincident with the development of the fig. At a season when the fig requires three months for formation and full ripening, the wasp does not emerge from the fig until that time. It cannot do otherwise, for it never leaves the fruit until it has ripened and softened, and it always enters it when it is in a certain immature condition. When a winter season prolongs the development of the fig, the growth and maturity of the wasp must also be prolonged.

The details above show how absolutely impossible it is that pollen could ever reach a female flower at the time it requires it without this wasp hatching from a ripe fig in which pollen has just been scattered, leaving the fruit with its body covered with the pollen and immediately flying to, and boring into, a young fig containing female flowers just ready for the pollen that the wasp has unintentionally brought with it. The wasp must enter the young fig to lay its eggs in certain gall-flowers at a particular time, otherwise those flowers will have withered and will be unsuitable for the wasp, and the true female flowers, destined for seed, must have pollen at just this time, otherwise they wither and dry up and never form seed. Hence the remarkable coordination in the development of both seed and wasp. The wasp is absolutely dependent upon this particular fig-species to perpetuate its kind, and the tree is equally and totally unable to continue existence without the ceaseless aid of this particular wasp. A tree might be planted and grow for one hundred years or more, but without the presence of this wasp there would never be any fertile seed formed in its figs, and it would ultimately perish with none to take its place.

Fig trees native to Fiji were studied during 1920 and found to be equally dependent upon particular wasps in each case.

Several species of Hymenoptera other than *Pleistodontes froggatti* were bred from the fruits of the Moreton Bay fig. None are true pollinators nor do they play any part in the development of the fig. They never bore into the young figs. All deposit their eggs into the fig-flowers by forcing the ovipositor through the fig-wall from the outside. Their larvae can serve only as parasites of the true fig-wasp, parasites of one another, or as simple plant feeders within the fig-flowers. All, so far examined, develop wholly within the fig-flowers and not on the fig-pulp. They have been excluded in the introduction of the true fig-wasp into Hawaii.

Mr. W. W. Froggatt, Government Entomologist of New South Wales, was the first to present an account of fig-wasps in the fruits of *Ficus macrophylla*. This appeared in the Agricultural Gazette of New South Wales for June, 1900. This interesting paper offered much of interest regarding the habits of *Pleistodontes froggatti* and other insects associated with it in the figs, and has been very useful for reference in connection with the details included in the present paper. In Froggatt's "Australian Insects" appears an excellent plate showing various views of the same fig-insects, illustrating some of their habits.

The most complete recent work on the habits of fig-wasps was published in the Philippine Journal of Science, Section D, April, 1913, by Mr. C. F. Baker, under the title, "A Study of Caprification in *Ficus nota*." Many of the details herein presented on the habits of *Pleistodontes froggatti* were identically observed by Mr. Baker in respect to the life-history of the particular wasp developing in and fertilizing the seed of *Ficus nota*.

Cunningham, in 1889, in the Annals of the Royal Botanical Garden; Calcutta, (Vol. I, Appendix), describes the flowers of *Ficus Roxburghii* and the effects of the presence of insects upon them. From his studies he concluded that it is not pollination that causes the developments, but the irritation caused by the act of oviposition. This species of fig is dioecious, one tree producing figs containing male and gall flowers and another tree bearing figs containing true female flowers capable of producing seeds. That the Smyrna figs can be pollinated artificially and develop mature fruit without the presence of insects has been demonstrated by Roeding in California. Similar tests should be made on *Ficus Roxburghii* before Cunningham's conclusions can be accepted.

The Moreton Bay fig is grown artificially in regions where the wasp herein discussed is not present, and in all such places no fertile seed is ever formed. In the Botanic Gardens and the Domain in the City of Melbourne, Australia, large, beautiful avenues of this tree have been planted. Fruits form in abundance, but no fertile seed has ever been formed here, according to Mr. Cronin, the Director of the Gardens. An examination of these trees was made to determine the cause for this, if possible. No *Pleistodontes* or fig-wasps of any species were found in the trees. A thousand figs were collected and each carefully examined. No seed development could be noted in any and no wasps in any stage were present. The pulp and seeds do not develop to any size and the fruits always fall to the ground in a hard, immature condition. The absence

Ficus eugenioides in the Domain, Sydney.

of the wasp easily explains this. Possibly the winters are too cold in Melbourne for the few wasps that may accidentally reach there occasionally from Sydney or the regions to the north. It seems more probable, however, that none have ever reached the region at a proper time or in a proper condition.

Large trees of the Moreton Bay fig were also found growing abundantly in Auckland, New Zealand. No figs ever mature there, no fertile seed is ever formed and a careful examination of much of the fruit on the trees soon showed that no fig-wasps were present. The tree has simply been introduced from Australia without the necessary wasp associated with it. Several splendid Moreton Bay fig trees were also found growing at Lautoka, Fiji. Examination of a large quantity of fruits from these trees also indicated the absence of the *Pleistodontes* wasp and of fertile seeds. Many other fig-wasps are present in Fiji, living in the native figs, but will not of course take to any but their own particular species of *Ficus*. The two mature Moreton Bay fig trees growing in Honolulu form no fertile seed and the fig-wasp has never occurred in them. These have been under the observation of Dr. H. L. Lyon.

Occasionally, when the succession of fruits among the Moreton Bay fig trees in Sydney is such that few figs are ripening near some tree on which most of the young fruits are just appearing, many of these young figs will become too old for proper fertilization before wasps reach them with pollen from some other tree. Hence these fruits fall to the ground prematurely, just as among the trees in New Zealand, Fiji, Honolulu, and Melbourne, and contain no fertile seed. One such tree was found in Sydney on January 5th, 1921, rather distant from any other fig trees and bearing a quantity of young fruits, most of which had not been reached soon enough, or at all, by fig-wasps. These fruits had accumulated on the ground in great numbers. Fifty-one of them were gathered from the ground and examined. None contained fig-wasps, which readily explained why they had fallen. Twenty-six fruits of better size that were still growing on the tree were then examined and each was found to contain from one to five fig-wasps. They had many days before entered these figs, carried the pollen in, laid their eggs, thus establishing proper conditions for the maturity of the fruit, and then died. Here it is quite evident that the isolation of the tree had permitted only a moderate number of wasps to reach it and bring about the fertilization of only some of its fruits. The remainder failed to mature in the absence of fertilization and fell to the ground prematurely, just as though there had been no wasps in the community.

On some trees figs were enclosed in a gauze bag when very young to prevent wasps reaching them at the proper time. None of these ever matured or developed fertile seed.

There is a constant succession of fruiting among most of the trees in Sydney, which have been under observation for several months, during a study of the wasp. Some trees will be just forming fruits, while the figs on others will be mostly ripe, or on some may be only one-half developed. There appears, however, to be somewhat of a seasonal development, the majority fruiting together. The ripe fruits were found to be much more numerous in Sydney in March than in December or January. Yet the variation in the fruiting of each

tree throughout the year provides a sufficiency of ripe and young fruits at all times to provide a suitable condition for the fig-wasp. Newly hatched females can thus nearly always find some young figs just right for the reception of their eggs.

It is interesting to note here that of the many species of imported figs growing in the Botanic Gardens in Sydney, none ever produce fertile seed, with one exception, and none have had their particular fig-wasps introduced with them. The exception is the Lord Howe Island fig, *Ficus columnaris.* It has been planted in the Gardens in Sydney. When it became old enough to form fruits, the *Pleistodontes* wasp of the Moreton Bay fig took to it and successfully bred in it, thus establishing pollination in its flowers and causing normal seed development. A large number of *Pleistodontes froggatti* have been bred from its fruits. It is, according to Mr. Maiden, botanically close to *Ficus macrophylla.* The fruits and flowers are almost identical. A quantity of seed of this tree was collected and sent to Honolulu in January, 1921.

Cunningham stated that *Ficus Roxburghii* in the Botanical Gardens of Calcutta is not attended by its native insect of Sikkim, but he did not state the local host of the insect he worked with in Calcutta.

On January 27th, 1921, several hundred well-grown figs from the Moreton Bay fig tree were collected in Sydney for shipment to Honolulu, with the fig-wasp contained within them. The fruits were just reaching maturity; some were still fairly hard and others were just commencing to turn yellow and soften. These all contained large numbers of living *Pleistodontes* pupae, many of which were about to hatch. The lot was divided in half. One portion was inserted in a cloth-lined shipping case, filled with trays to hold the figs apart. This was placed on the upper deck of the steamship "Ventura." The other portion was placed in a cardboard box, each fig being wrapped separately in paper and the box then tied securely in a canvas bag. The bag was then placed in a refrigerating room, aboard the same steamer, in which a temperature of about 45° F. was constantly maintained. About two weeks later the material reached Honolulu. All wasps in the figs on deck were dead, while the cold-storage lot arrived in good condition and 2000 living females were liberated in the two Moreton Bay fig trees then in Honolulu. Females were soon observed to enter young figs. This should thus ensure their establishment in Hawaii for use in years to come when the quantity of seed which has been collected in Sydney, in connection with the present study of this insect, has been germinated in nurseries, set out in the forests, and finally matured to fruiting trees.

Attached herewith are photographs of Moreton Bay fig trees as they appear in the Botanic Gardens and Domain in Sydney. They indicate the splendid proportions to which the tree grows and the great depth of shade cast. These trees are all growing in a very shallow soil, covering a stratum of solid sandstone. The tree is generally recognized as capable of withstanding very adverse conditions. Mr. J. H. Maiden, Government Botanist and Director of the Botanic Gardens in Sydney, states in the Agricultural Gazette of New South Wales for October, 1908, that "It will grow amongst rocks where scarcely anything else will grow, and it will stand being blown upon by fierce winds and

EXPLANATION OF FIGURES.

Figure 1.—Ripe Moreton Bay fig, cross-section, showing mature female flowers (Seeds), gall-flowers from which fig-wasps have hatched, and ruptured pollen sacs or male flowers. About natural size.

Figure 2.—(A) Young female flower just ready for reception of pollen. (B) Young gall-flower at proper age to receive egg of fig-wasp. (C) Immature male flower in the same young fig with (A) and (B). All drawn to the same scale. Enlarged about twenty times. *ps.*, pollen sacs; *stig.*, stigma; *sty.*, style; *ov.*, ovaries.

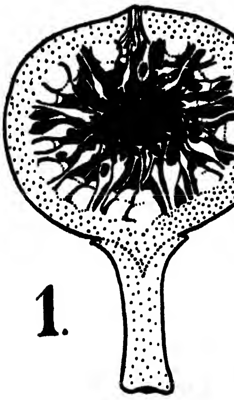
Figure 3.—Very young fig, showing bracts still enclosing the fig and covering the apex and thus preventing the wasp from entering. The flowers within the fig are not ready for pollen carried by the wasp or for the wasp's eggs until these bracts have just opened, as in Figures 4 and 5. Wasp awaiting opening of bracts. All enlarged about one and one-half times. *b.*, bract.

Figure 4.—Young fig, showing characteristic position of female fig-wasp boring into the apex. The body projects in midair, as shown, as soon as the head becomes well imbedded. Enlarged about four times.

Figure 5.—Young fig, showing usual position of female fig-wasp after head has penetrated well into the fruit. The legs from here on assist in the entrance and the wings are about to be broken off. Enlarged about two and one-half times.

Figure 6.—Portion of inner wall of a young fig, showing female ovipositing into a gall-flower. This illustrates her characteristic egg-laying position. Note the absence of wings and antennal joints, and that she has selected a gall-flower in which to lay. Much enlarged.

Figure 7.—Fully developed fig, showing female wasps boring out of it. At this time the females are covered with pollen. About natural size.



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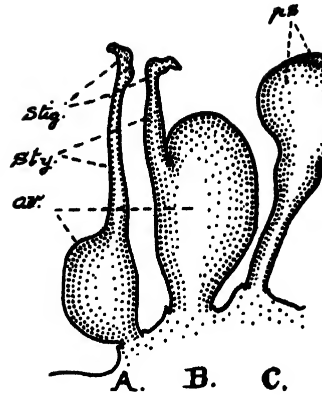

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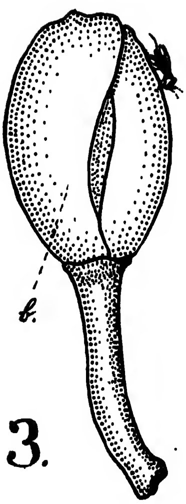

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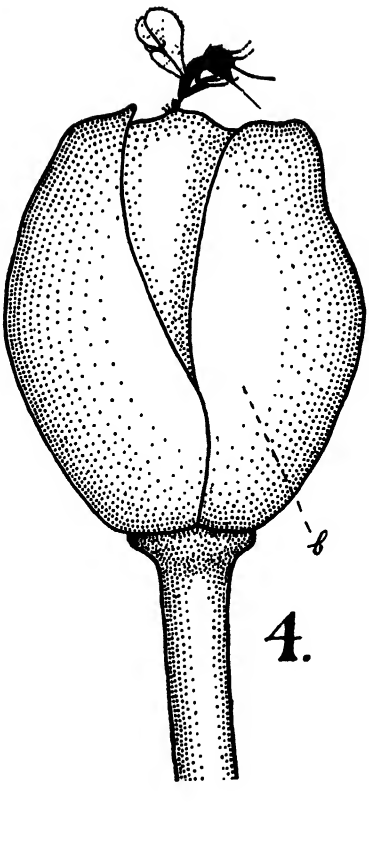

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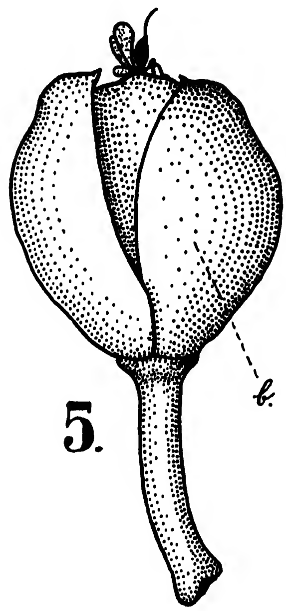

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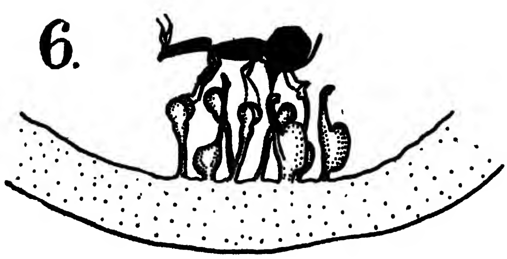
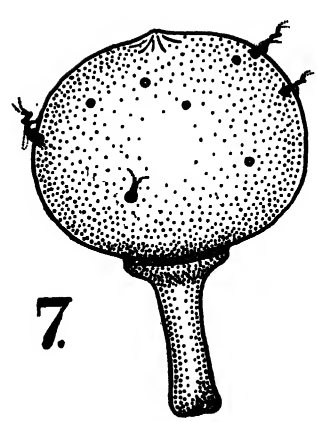




7.

being hacked about and otherwise ill-used. I admit that it can be put in the wrong place; but a Moreton Bay fig, with plenty of room so that it can live its life, is one of the most beautiful of trees, while its foliage and fruit are nutritious to stock, and its umbrageous head affords a grateful shade. I have drawn attention to the value of this tree to dairy farmers. The observations were original as regards Australia, though I afterwards found that leaves of other species of *Ficus* were used for feed in parts of India.

"Bearing in mind the way in which these and other native figs flourish exceedingly in the poorest soil, that cattle devour the leaves and branchlets greedily, that they will submit to persistent hacking back to an extent which will kill most other trees, it seems a matter for consideration that these trees should always be planted for shade purposes on dairy farms and they should even be planted as a reserve of fodder in stony, sterile places where no grass will grow."

Mr. J. S. Walford of Sydney has written of the Moreton Bay fig as follows: "I think I may with safety state that Moore Park (Sydney) will carry all the year round, good season and bad, as many horses as any equal acreage of the best of country. This statement is borne out by the mob of horses that may be seen any month of the year grazing in one or other of the paddocks; and it is only made possible by the Moreton Bay fig tree. The stock eats greedily the figs and fallen leaves. I have seen cows in the Domain leave grass which was fetlock high to eat ravenously the leaves on the lopped-off branches of the Moreton Bay fig trees.

"If the tree will grow inland, immense quantities of leaves and bark could be obtained in dry weather and the branches could be cut back to the bare stump, which would again grow luxuriant foliage by the time another drought occurred. How hard it is to kill a Moreton Bay fig tree may be judged from the fact that some years ago, when the row of trees was removed from Government House grounds, the roots were cut through and some of the stumps were carted to Moore Park and planted. These stumps struck and are now fine trees."

Mr. Maiden fully corroborates the above statements.

It is usually called a "dirty tree" in Sydney, owing to the large quantity of leaves and fruit that constantly accumulates beneath it. As a forest tree this is an exceedingly desirable character. A deep, spongy mulch, with splendid water-holding capacity, is certain to form under these trees.

Mr. C. Hedley, of the Australian Museum, Sydney, states that in the vicinity of Moreton Bay, Queensland, where this fig is indigenous, it normally starts in a forest as an epiphyte. The fruit is eaten by birds and the seed dropped in the crotch of some tree. There it germinates, sending roots down along the surface of the limbs and trunk, finally reaching the ground, taking root, growing larger and larger, ultimately strangling the tree upon which it started, and thence continuing from a large vine to an enormous tree. It is possible, however, that the tree may occasionally start naturally from a seed which has germinated on the ground or in a rock-crevice. Seedlings have been found growing beneath large trees in Sydney, though scarce. They do not survive, however, under park conditions.

Photographs are also shown of other species of figs, possessing splendid forest qualities, which are now growing in the Botanic Gardens in Sydney. Seed of all has been collected and forwarded to Honolulu during January, February, and March, 1921, together with specimens, for future reference, of the particular fig-wasps associated with each.

NOTE.

The fig insects sent from Australia by Mr. Pemberton were liberated on February 9th. It is still too soon to be quite sure that they have failed to establish themselves, but up to the present we have found no mature figs on the trees where the insects were liberated. If a single fig in an upper branch of the tree came to maturity it would be enough to start a colony. If they have not established themselves it must be because the pollen they carried with them had not survived the two weeks' journey in the cool chamber.

F. M.

Boilers and Economizers.*

By Dr. D. S. Jacobus.

During the year 1920 the trend of boiler design has been toward the use of a greater number of tubes in height for a given class of work. Adding to the height of the boiler adds to its efficiency with a relatively small increase in draft resistance. By adding to the height of a boiler, leaving the lower part of it and the stoker and furnace the same, the efficiency is materially increased for a given amount of steam produced, the curve of efficiency at different ratings being both raised and flattened. Among large boilers recently installed are some which evaporate in the neighborhood of 150,000 pounds of water per hour under actual conditions, this size being a convenient one to use in connection with the largest steam turbines.

Boiler pressures are also being gradually increased, a number of installations having been installed in which the working pressure is 350 pounds with a superheat of from 200 to 225 degrees, and with some changes in design there seems to be no reason why higher pressures are not perfectly feasible; in fact, test boilers have been built for 500 pounds pressure and over.

The question is often raised as to whether it will pay to install economizers. Each case must be considered by itself. As the price of fuel increases, naturally the use of economizers will increase. In considering the use of economizers, the additional efficiency secured through adding to the boiler surface by increasing the height of the boiler should be taken into account. If we start with a boiler, say, 14 tubes high, adding tubes so as to make the boiler 16, 18

*** Reprinted from "Power," January 4, 1921.**

or 20 tubes high, will, for a given amount of fuel burned per hour, result in each case in added efficiency. This additional efficiency is secured without a very great increase in the draft loss, as much of the draft loss in boilers comes through the turns that the gases make over the baffles. The higher boilers can in most cases be operated with natural draft up to the desired capacity, whereas should economizers be installed an induced draft is ordinarily required. In some cases the simplification of the plant by using the higher boilers as compared with one having economizers warrants the use of the higher boilers.

To show how misconceptions respecting boiler performances arise, consider the case of a small plant having several boilers, one of which is uneconomical with a low draft resistance. The flue gas temperature for this unit will be higher at a given rating than for the others, and the amount of power obtainable from it will be higher than from the others. This would be especially noticeable if the uneconomical boiler was shut down, as there would then be no additional draft through the higher temperature of the gases from the uneconomical boiler. The operating crew would soon find that when the uneconomical boiler was cut out of service the capacity would fall off more than in cutting off any of the others, and they might come to the conclusion that the most uneconomical boiler was the best one in their plant.

We are now at a point where we should not allow impression to take the place of facts, and we cannot afford to adopt the easiest way if this means an undue loss in economy. As the price of fuel increases, additional capital investment is warranted, and an equipment for securing a higher efficiency usually means more complication and necessitates a higher class of operation than the more simple arrangement. Our best run plants are already on a par with laboratories in the care with which they are operated and the skill and ability of those in charge. There are still, however, many plants where the fuel consumption is 50 to 100 per cent higher than it might be. Each time a wasteful plant is replaced by an economical one we save fuel for future generations and practice real conservation. [W. E. S.]

An Innovation in the Manner of Liming Cane Juice.*

By Maurice Bird.

It has long been recognized that there is a large undetermined loss of sucrose in cane juice during the interval of its expression from the cane and its reception of lime and heat, this loss being due to the acidity and viscous ferments inherent in the juice.

Even washing and liming the mills at night still leaves the rollers, carriers, mill bed, juice channels, etc., subject, during the long hours of grinding, to the action of this acidity and its accompanying ferments.

* From the "Louisiana Planter," Vol. LXVI, p. 184.

As it is largely customary now, in multiple crushing, to return the last mill juice, which contains the bulk of maceration (dilution) water, to the megasse emerging from the first mill, it occurred to me that if this juice were limed and sterilized with formaldehyde, these chemicals would be carried to practically every part of the crushing plant and thereby minimize or entirely remove the loss of sugar at this point.

Above the third mill juice channel, therefore, a cylindrical tank was installed, containing a mechanical stirrer and having a valve at the bottom.

Carefully prepared milk of lime was strained into the cylindrical tank and a pint of formaldehyde added twice a day.

By means of the valve a small stream of milk of lime was allowed to run into the last mill juice which took with it the formaldehyde throughout the crushing plant.

As the results were evidently beneficial, more and more lime was added at this point until the whole of this chemical, needed for clarification, was run in here.

The temperature of the last mill juice at this point, when the lime is added, was 120° F., due to the friction at the rollers and to hot water being used for maceration. It seems, therefore, reasonable to conclude that this clarification in the megasse, as it were, must result in more or less of the precipitated impurities of the juice being strained off by the megasse and consequently relieving the work at the filter presses to a greater or less extent.

That the clarification was greatly improved seemed beyond any doubt, and the sugar cured more easily than previously; also the recovery of sugar from the juice was better, though other causes which happened to exist at this time also aided the increased recovery.

A result that we had not anticipated was that by liming in this way a practically neutral juice could be obtained from the mills, and the annoying and deleterious variation from slight acidity to slight alkalinity and to acidity again, previously experienced, was entirely removed, the least departure from neutrality being easily corrected by regulating the valve admitting the milk of lime to the juice.

Other factories are following our practice of liming the last mill juice, and though of course it might be in vogue elsewhere, I thought, since I have never heard of it before, that it may be novel and that some of the readers of "The Planter" might like to give it a trial. [W. R. M.]

CANEFIELD. *British Guiana,* February 9, 1921.

Report of Committee on Agricultural Progress of the Louisiana Sugar Planters' Association for the Year 1920.*

* * * * * * * * * *

Under the circumstances, the crop had to be grown with field laborers who took full advantage of everything, knowing that they were very much in demand. They received high wages and gave in return a careless and less efficient class of work. The planters had to make the best of the situation, and went ahead with field work meeting all difficulties.

It was the scarcity of labor, high wages, high price of mules and scarcity of feed that caused tractors to come more to the front in 1920. In the fall preparation of land the four-wheeled 12–20 and Thompson plow was used extensively in destroying stubbles and plowing land that was in corn and peavines. In this work the tractor averaged about six acres per day, doing the work of four two-mule plows and one four-mule burster. The two-wheeled tractor with stubble destroyer attachment, with one operation, was used in fall plowing, averaging six to eight acres a day.

The caterpillar type of tractor was used in an extensive way, and from all indications in a greater variety of different works. The Georgia plantation at Mathews used this type of tractor during the entire period of cultivation, also finally laying by the crop. The labor situation in this section became so acute

Labor Shortage and Tractors.

From the time that the first work on the crop started, all through the season cane farmers were confronted with shortage of labor and a high scale of wages. The enormous profits that were made in rice the year before caused a large increase in rice plantings, not only in the rice sections, but also in the sugar territory in the heavy types of land. There were quite a few cases where sacrifices were made in the way of plowing up fair stands of stubble and planting rice.

With these conditions coming up, the demand for field laborers increased to such an extent that changes in the systems of field work on plantations had to be made. There was very little cooperation between the two classes of planters in trying to solve labor problems. The rice planters were bent on planting and growing their crops, and set the pace in paying high wages which sugar planters had to meet by corresponding increases in order to hold their labor. that it was only the use of tractors that enabled the management to successfully cultivate the crop. In these cultivation operations the Magnolia cultivator, equipped with two small turning-plows and a middle burster, was used, and the work performed quicker and better than with mule teams.

There had been so many troubles reported on unsatisfactory tractor operation on account of breakdowns, caused mostly by bad manipulation on the op-

*Louisiana Planter," Vol. LXVI, pp. 185–189.

erators' part, and lack of proper organization on the plantation, that the system used by the Georgia group of plantations has, in the opinion of the committee, been a marked advance in agriculture progress. Mr. Sommers, the general field manager, with hard work and close attention, devised a system that gave excellent results with tractor work. The entire lot of tractors, eighteen in number, were under the supervision of a tractor mechanic, who was stationed at a repair shed, and devoted his entire time to the repairing and upkeep of tractors. Another mechanic, provided with a truck or car, acted as field runner, and devoted his entire time to see that the tractors were kept in running order in the field. In case of breakdowns or troubles overseers simply called this man, and he either repaired the tractor in the field, or in case of serious trouble moved it to the shed where the mechanic could make the necessary repairs. This system relieved overseers of handling or trying to handle a problem that is new to them, and gave them an opportunity to get more out of their tractors and at the same time attend to other field work.

The implements that were used with the tractors were all rigged up by the plantation blacksmith, and in most cases the regular plantation implements were used. In a way this was a disadvantage, for it left the manager to his own resources to provide implements to use with the tractor, but, on the other hand, it was an economy in saving an expenditure by the use of the old implements instead of purchasing entire new sets of implements. At first preparing the implements presented difficulties, but as the blacksmith worked and gained experience, and besides obtained improvements in shop fixtures and equipment, the work was carried out on a satisfactory basis.

Tractors were used to good advantage in planting cane, going through usual operations:

(1) Two rows opened at one time.

(2) Two rows covered at one time.

(3) Two rows rolled and one middle opened at one time.

In the field work with tractors on Georgia, one man operated the tractor, and one man operated the implement. On account of the strenuous work involved in running a tractor, an entire day was found to be too much of a strain on the operator. An arrangement was made where the tractor and implement operators alternated, each man giving half of the day to running the tractor. This method gave much better results in the way of increasing the efficiency of tractor work.

The opinions of planters regarding the use of tractors on sugar plantations indicate that there is need of a good deal of work on this problem before tractors can be generally accepted for practical field work. From reports received by the committee from different sections of the sugar parishes where tractors were used favorable and unfavorable comments have been made. It is generally conceded by the majority of planters that when tractors are in good running order, they do all classes of field sugar cane work quicker and cheaper than with mule teams. This cost, however, is not at all fixed, and with the frequent stops, breakdowns, high costs of tractor parts, the tractor work is often much more expensive than mule team work.

The question of the right implements to be used with tractors has prevented a more general use of tractors. As a general rule tractors are sold without implements, and the whole thing of equipping the tractor for field work was left to the ingenuity of the planter. On plantations where officials in connection gave this matter some attention, with a lot of trouble, implements were set up and some good work was done. Other planters, not having the time and proper conveniences, only used their tractors in a limited way.

The year 1920 can be termed a good tractor year. The high wage scale, scarcity of labor and high cost of mules, caused a more general use of tractors. On the whole the work performed by tractors last year was far ahead of any other year. In special operations, such as breaking land, laborious discing and hauling, the tractor has surpassed mule teams and can always be used in these lines of work to advantage. With the change in conditions now occurring, wages going down, labor more plentiful, and mules at prewar prices, there will be a keen competition between mule teams and tractors, and supporters of the latter will be compelled to remedy the present day evils for the tractor to make progress on sugar plantations.

CULTIVATION OF CANE WITH TRACTORS AND MAGNOLIA CULTIVATORS.

Date	6–7	6–8	6–10	6–11	6–14	6–15	6–15	6–16	6–29
Number of tractors	12	12	14	13	13	14	14	14	16
Total time, hours	113	103.5	105	151	143	152	149.5	145.5	156
Total Acres	140	118	156.5	177	184.5	196	194	195	204
Gallons gas used	147½	131	153½	189	187	197	194	182	184½
Quarts oil used	26	15½	23	20	23	34	34	45	30
Quarts 600W used	17	17	23	21	17	24	24	34	28
Pounds grease used	11	8	14	13½	12	15½	15½	13	18
Time lost—breakage	4½	3½	..	..	3½	..	..	2	2
Time oiling and adjustment	11	14	18½	22	19½	21½	21	21	21
Average number working hours, 1 tractor	9.4	8.8	7.5	11.6	11	19.8	10.7	10.4	9.8
Average number acres per day, 1 tractor	11.6	8.9	11.1	13.6	14.1	14	13.8	14	12.7
Cost per Acre	72c	76c	65c	72c	66c	66c	67c	67c	64c

Calculations on $4.00 per day for tractor and implement operators.
Gas, 30c per gallon; oil, 30c per quart; grease, 25c per pound.

Fertilization of Cane.

The Extension Division and American Cane Growers' Association conducted co-operative sugar cane fertilizer demonstrations on sugar plantations in 1919. The results of this work helped materially in the fertilization of the 1920 crop in the way of giving planters information on the best sources and amounts of plant food to use in fertilizing their crops. The use of raw materials and a preparation of mixtures on the plantations proved the most economical method and netted savings of $25 to $50 per ton over commercial fertilizers containing the same amount of plant food. Nitrate of soda and calcium cyanamid were the cheapest forms of nitrogen, and it was on the results of the fertilizer

demonstrations that recommendations of the use of the former were made in preference to fertilizer materials that were from 25 to 100 per cent more expensive.

On a large number of plantations fertilizers were applied to both plant and stubble cane. This is quite a change from the old way, as the plant cane is not generally fertilized. The yields of plant cane and stubble were increased and gave returns which warranted the use of fertilizers. However, the storm which occurred in September was very injurious to the cane crop, and damaged the yields about 25 per cent, also causing low sucrose and purity juices. This was one of the main factors that prevented fertilizers from showing up to better advantage.

In the application of fertilizers the committee has obtained reports from several plantations that have made real progress in handling fertilizers. In West Baton Rouge, Cinclare used mixtures of acid phosphate and nitrate of soda in different proportions on various types of lands. The preparation of the mixtures, which is an undertaking that is considered a big job by many planters, was simplified and made rather inexpensive by the use of large wagons and mixing in the field. The wagons were only charged with a limited number of the two kinds of fertilizers, leaving enough room for mixing on the rest of the wagon bed. Each wagon was provided with one extra hand, who, along with the driver, mixed the fertilizer and loaded same directly into the meal boxes as needed. This saved resacking and kept the distributors supplied with fertilizers, so that they averaged ten acres per day.

The Colonial Sugar Company prepared mixtures of acid phosphate and nitrate of soda in a warehouse, and at one end, a small addition was constructed where the fertilizers were screened, crushed and mixed by hand, and resacked. This work was done at a cost of about $1 per ton. Similar mixtures of fertilizers were prepared on somewhat the same basis on the following plantations: Southdown, Sterling, Columbia, St. John, Longview, Laurel Grove and Bellevue.

Calcium cyanamid was used as a source of nitrogen on Raceland and Salsburg Plantations. Acid phosphate was also applied, the two fertilizers, however, being unmixed in two applications. The two application method of fertilizer to cane was found disadvantageous, due to doubling the cost of putting down fertilizer, and causing the use of more teams when they were in great demand for other work at this time.

The management of Salsburg plantations reports excellent results with the use of cyanamid in the way of increased tonnages and giving juices of higher sucrose and purity. A report was also given where it was found that nitrate of soda caused a prolongation in the growth of cane, showing upon anlysis of juice low percentages of sucrose and purity. This condition may have been caused by a late fertilizer application, as results in other sections where cane was fertilized with nitrate of soda early in the season gave good results.

The American Cane Growers' Association and Louisiana State University Extension Division co-operating with the United States Department of Agriculture conducted sugar cane fertilizer demonstrations in the following parishes: Assumption, Ascension, Lafourche, Terrebonne, St. Mary, Iberville, West Baton Rouge, East Baton Rouge, Pointe Coupee, Rapides, and St. Martin. In this

co-operative work the following County Agents took an active part in supervising and getting final results: F. M. Bacque, Lafayette; B. Mackay, Ascension; H. Lesseps, Iberville; R. J. Badon, St. Martin; W. H. Humble, Rapides, and A. B. Curet, Pointe Coupee.

The committee, on request for a complete report on the results of sugar cane fertilizer work carried out in 1920, has been granted this request by Mr. W. H. Chaffe, Secretary of the American Cane Growers' Association, and Mr. W. R. Perkins, Director of Extension, and submits same as an important line of agriculture progress in 1920.

Results of First-Year Stubble.

The best returns were given by a mixture of 300 pounds nitrate of soda and 250 pounds acid phosphate, which showed 12.37 tons per acre more than the check and a net gain of $63.75. Analysis showed good sucrose and purity. A mixture of 200 pounds nitrate of soda and 500 pounds acid phosphate gave increase of 7.89 tons per acre and a net gain of $35.53 per acre.

On Columbia 400 pounds prepared fertilizer, 6.58 per cent nitrogen, gave an increase of 6.6 tons per acre and a net gain of $29.40 per acre.

On David, Evergreen, and St. John plantations, where 300 pounds nitrate of soda were applied on one-acre plots, gave an average increase of 6.73 tons per acre and a net gain of $30.81.

Mixtures of cotton-seed meal, nitrate of soda, and acid phosphate gave good results; 200 pounds cotton-seed meal, 100 pounds nitrate of soda, and 100 pounds acid phosphate gave on David plantation an increase of 6.32 tons per acre and a net gain of $28.38.

Results on Plant Cane.

Special attention is called to mixtures of sulphate of ammonia and acid phosphate. These plots were conducted on one plantation on ¼-acre plots; 150 pounds sulphate of ammonia and 300 pounds acid phosphate gave an increase of 7.85 tons per acre and a net gain of $35.90. One hundred and fifty pounds of sulphate of ammonia and 250 pounds of acid phosphate gave an increase of 5.97 tons per acre and a net gain of $27.05.

In the comparisons between prepared fertilizers and home mixtures the former was given by the Soil Improvement Committee, by their agronomist, Mr. J. C. Pridmore. The committee has gone over the subject with Mr. Pridmore, and find that valuable assistance is being given by the Soil Improvement Committee from an impartial standpoint in soil fertility work to find out the best plant food requirements for growing crops.

A series of fertilizer tests was conducted on plant cane, using one-acre plots, fertilizer at the rate of 400 pounds, 600 pounds, and 800 pounds per acre. The average results from 12 plantations with 400 pounds prepared fertilizer shows an increase of 3.8 tons per acre, and a net gain of $9.72. The 600 pounds application on six plantations shows an average increase of 5.34 tons per acre, and a net gain of $13.14. The 800-pound application showed an increase of only 4.32 tons per acre and a loss of 82c per acre.

Diseases of Sugar Cane.

At the first mention of disease of sugar cane, the new sugar cane mosaic disease, which was first identified in this State in the spring of 1919, has been attracting the most attention. Special surveys have been made in the sugar parishes by the United States Department of Agriculture officials of the Sugar Plant Investigation office during the summers of 1919 and 1920. The American Cane Growers' Association and Louisiana State University Extension Division has also given considerable attention to the Mosaic disease and the following article was prepared on the subject:

Mosaic Disease of Sugar Cane—Infestation.

The mosaic disease of sugar cane was first recognized in this State in the spring of last year. It is very probable that it has been here for a number of years, having been introduced from the tropics through the importation of some new variety of sugar cane. The regions along both sides of the Mississippi River, taking in the parishes of Plaquemines, Orleans, Jefferson, St. Charles, St. John, St. James, Ascension, Iberville, East Baton Rouge, West Baton Rouge, Pointe Coupee, St. Mary, Iberia, St. Martin, and West Feliciana, were found to be infected with mosaic disease. The plantations between Lutcher and Reserve, around Burtville, Gonzales, and Angola, on the east side of the river, are more heavily infected. On the west side the plantations around Waggaman, Vacherie, Lauderdale, Hahnville, and Addis are heavily infected.

Along Bayou Lafourche mosaic occurs on both sides all the way down. Plantations around Belle Alliance, below Napoleonville, Raceland, Mathews, and Lockport are already showing 10 to 20 per cent infections. In Terrebonne the disease seems to be starting, and is not as widespread. The parishes of St. Landry, Lafayette, Vermillion, Avoyelles, and Rapides are free of mosaic.

In comparing the disease at the present time and last year at this time, a general spread is noticeable everywhere. In places where traces occurred infection runs 5 to 10 per cent. Plantations that showed 40 to 50 per cent are now showing 80 to 100 per cent. This is a rather remarkable increase, and shows to what extent it will spread if control measures are not taken.

There are two kinds of mosaic infections, primary and secondary. A primary infection is where the disease is in the seed or cutting and makes its appearance as soon as growth starts. Secondary infection is where the disease is just showing up in previously healthy plants, having been passed during the growing season from diseased to healthy plants. This form of infection is invariably found in the upper or young leaves and is not present in the older lower leaves. Unless a person is especially familiar with this infection, it will be passed up. This condition complicates control work as far as seed selection is concerned, for seed cane having secondary infection will produce mosaic cane. On account of the difficulty of detecting this infection, there is a certain amount of uncertainty in making a sure selection.

The varieties of cane grown in this State are all subject to mosaic disease. D 95 succumbs to the attacks of the disease, and can be classed as an unprofitable cane under mosaic conditions. Infected fields of this variety have a mottled yellow unhealthy color, and generally a noticeable dwarfness or stunted growth.

The latter condition does not always occur in plant cane, but is invariably the case in stubble. D 74 plant cane, with good cultivation, fertilization, and in good land, with heavy mosaic infection makes a good growth. Plant cane under less ideal conditions shows some injury, growing less vigorously. D 74 stubble shows more effects of the disease, attacked plants being of an unhealthy cast, the stripes in the leaves being a decided yellow and sometimes brown color. In a good many cases the cane is stunted and spindling.

Native Canes—Lapice—Striped and Purple.

All three of the varieties are subject to mosaic disease. The plant cane seems to show less injury. In stubble mosaic has somewhat the same effect on these canes as D 95, stunting the growth and giving the cane an unhealthy yellow color. It is quite characteristic to see small stools completely dwarfed by the disease.

Louisiana Seedlings.

L 511, L 243, L 231, all three of these varieties subject to mosaic. The L 511 seems to show some resistance, showing smaller percentage of infection in heavily infected sections. Unlike other varieties, L 511 when attacked with mosaic shows up on the stalks in the form of long, thin, purplish streaks. This characteristic of L 511 was first noticed by Mr. W. G. Taggart and Dr. C. E. Edgerton of the Experiment Station. This would be a valuable point in favor of L 511 in case it should be proven good enough for plantation use, in the way of discarding mosaic seed cane.

Prevention and Eradication.

Mosaic disease has been found to occur on all classes of lands. Heavy infections have been found on virgin soils, and in well cultivated fields. On the other hand, abandoned stubble cane, overgrown with grass and weeds, has been found free of mosaic disease. Poorly drained fields have also been found mosaic free. This is to emphasize that neglected fields, lack of cultivation, and poor lands are not causes of mosaic disease, and also that it does occur on the richest as well as the poorest types of soils.

On places heavily infected with mosaic a special plan will have to be followed to obtain satisfactory results. In such a case it will be almost out of the question to obtain mosaic-free seed cane from the same plantation and selection will not be practical. The use of healthy seed from an uninfected area will be the easiest way. This seed should be planted a safe distance from infected fields (from ¼ to ½ mile). This can be accomplished by separating the fields with leguminous crops, such as velvet beans, soy beans, cowpeas, etc., avoiding such crops as sorghum and corn, which are also subject to mosaic disease. Fields of selected seed cane should be used for planting purposes only, and extended as rapidly as possible, replacing mosaic cane. This is a gradual system and will take several years to eradicate the disease. However, it will easily pay for itself in reseeding plantations with healthy cane, and prevent a coming danger of deteriorated cane, which will eventually be the outcome where mosaic is disregarded.

In cases of light mosaic infection, where the disease is not widespread, the

rogueing method is recommended. This consists in actually getting rid of mosaic plants by digging them out. This method can be used to advantage in preventing further spread of mosaic in stubble cane that is to be used for seed. In such cases the cane should be rogued several times in order to get cases that would develop later on from secondary infection. On the H. C. Minor estate this method is being tried this year on Southdown and Hollywood plantations. The results up to now are very encouraging. Fields that were rogued three times show less than 1 per cent infection, while unrogued fields of the same cane run from 5 to 10 per cent.

The rogueing of plant cane is not recommended unless the infections are very light, in which case it would be a good practice. The growing of second year stubble should be entirely discontinued, due to the fact that mosaic seems to be more virulent in stubble, especially old stubble.

The use of better seed cane, instead of scrappy stubble heavily infected with mosaic, root disease and riddled with borers is another measure that will help in the fight against the disease.

There is no cure for mosaic disease; fertilizer applications, liming, good cultivation, etc., have not stopped the disease. It is a disturbment in the sap of the cane, the cause unknown, which checks normal development of the cane and reduces the tonnage. Mosaic seed cane produces mosaic cane, which spreads during the growing season, diseased plants infecting healthy plants. It seems logical, therefore, for the planter to take the same steps that were taken twenty years ago, when D 74 was distributed in lots of six stalks each to planters over the State for the purpose of replacing the native varieties. Even with this small outlay of seed cane to start on, it did not take many years for large plantations to replace the inferior native canes. Today we are confronted with a threatening danger to all of our cane varieties. Instead of the six-stalk basis, it is possible to obtain mosaic-free cane from uninfected areas in quantities large enough for planters to start on the basis of 5 to 10 acres, under which system it would only take several years to reseed a plantation with clean seed.

Mosaic Disease—Method of Eradication Employed by Estate of H. C. Minor.

"In the early part of 1920 'The Louisiana Planter' brought to our attention the serious consequences resulting from mosaic disease in Porto Rico. A short time later the Agricultural Extension Service sent out a bulletin carrying the same information, and outlined the methods which had been found practicable in combating the disease. However, it was not until we were visited by Mr. Gouaux that we decided to make a fight on mosaic disease along the lines followed in other countries. Our practice was about as follows:

"One of the assistant overseers, whom we felt would give conscientious attention to the work, was designated to stay with Mr. Gouaux until he thoroughly learned to identify mosaic disease. After working one day with Mr. Gouaux he found that it was not always an easy matter to identify the disease, and feeling that he might forget the distinguishing marks, he transplanted four diseased stalks to his garden, which he could study frequently. (A few weeks later a non-diseased stalk was added to the plot. These stalks grew quickly under constant attention, and a few weeks later we noticed that the healthy cane

became infected by contact with the diseased stalks. This plot was used during the year to instruct others who were interested in mosaic disease.)

"Mr. Gouaux at this time spent two days in going over six plantations in the vicinity, and our representative was with him during this interval, and at the end of two days he felt that he could identify the disease with reasonable certainty.

"We found the disease in many widely separated fields, and it was apparently more prevalent in stubble cane than in plant cane. Some fields were more heavily infected than others, but in no case could we find an infection estimated to be greater than 1 per cent. Other fields were apparently free of the disease. At this time, which was about the middle of May, we decided it would not be practicable to rogue the plant cane fields, but would concentrate on those plats of stubble which were freest of disease, and from these plats would come the seed for planting the 1921 crop.

"The plan followed at Hollywood plantation well illustrates the work done, and the costs were accurately kept. The records show that rogueing was commenced June 15th. Two hundred and eight acres of stubble were on the place. While we at first attempted to rogue the whole stubble acreage, we later discarded forty-five acres which were rather heavily infected, and from which we did not intend to use any seed. The assistant overseer before mentioned was put in charge, and he selected one of the white field hands who was known to be honest and painstaking, as the best available man for the job. We thought that one man could eradicate the relatively small amount of diseased cane which we expected to find. He quickly learned to recognize mosaic disease. He carried a spade, and wherever he found a diseased stalk he dug out the stool and dropped the sick cane between the rows. He was able to cover, taking two rows at a time, an average of thirteen acres per day, but to cover it more quickly before the cane got too high to make the work impracticable, this man was given an intelligent boy of 16 years of age, the son of the overseer, as a helper.

"We assumed that once over would be all that was necessary. Such, however, was not the case; here and there over the field a few infected plants were discovered, so a second trip was made, and in places surrounding the spots where the first rogueing was done a number of infected plants were found, which indicated that infection spread before the diseased plants had been cut out. Other places in the field revealed diseased plants, some of which we are very sure were not infected when the first survey was made. The second survey was completed August 25th, and the work was discontinued because the cane was so far advanced in growth that it was not practicable to rogue further. But knowing the many diseased stalks that were present, we determined to eliminate as many as possible when planting began. When we began cutting seed these two men worked among the cutters and threw out all diseased plants which they could identify. We found it was much easier to recognize the sick plants in the later stages than when the work was first begun. We also discovered that it was almost impossible to identify the diseased from the healthy cane while wet with dew or after a rain, so that elimination was never attempted until ideal weather conditions prevailed.

"The accompanying table gives an analysis of the costs. The amount expended is not large. The cost per acre is small. At present we are not able

to say to what extent the work was effective. We are awaiting the development of the coming plant crop with keen interest in this regard, and confess a certain amount of trepidation. For the coming year we expect to continue the work, and feel that if the rogueing method is effective in combating the disease that we can make much better progress in 1921 than in 1920, for many of the employes can now easily identify the disease, and we will not wait until so late in the season to begin work. Already in stubble we can find diseased plants, and by April 1st it is our intention to start rogueing.

Summary of Costs.

Number of days' work put in, June 15th to August 15th, 31.
Total cost for this period, $64.25.
Acreage covered, 208.
Cost per acre, 31 cents.
Days put in during planting season, 12½.
Total cost for this period, $24.
Cost per acre, 11½ cents.
Total cost, $88.25, or 42½ cents per acre.

Cover Crop for Fall Plant Cane.

The growing of a cover crop on all plant cane is a work of the Louisiana Sugar Experiment Station. The results of the experiments conducted at the station during a period of years show an increase of about four tons per acre on fall cane where clover was grown as a cover crop on fall cane, and turned under in the spring, over fall cane where no cover crop was used.

This good work of the experiment station, which had only been discussed and not used in a practical way, was started on a small scale by Mr. S. F. Morse on plantations in the State. From results of 1919, the acreages of the fall cover crop were increased on the following plantations: Reserve, Colonial Sugars Company, Raceland, Salsburg, and J. Van Beary & Co.

On plantations where the cover crop was used last year the acreages on this year's fall cane were increased, some plantations planting 300 to 400 acres. From all reports received, the clover cover crop is giving good results. At first planters were inclined to think that a dense growth of clover on the cane would conserve too much moisture and seriously impair cane stands. The reports received during the two years tried out show no injuries from this source.

The clover used for the cover crop is known as *Melilotus indica.* It is an annual sweet clover with a yellow blossom, known as sour clover in the west. This clover is different from *Melilotus officinalis,* a biennial yellow blossom sweet clover growing on ditchbanks in Louisiana.

In planting *Melilotus indica,* 18 pounds of seed per acre is used. The seed is sown by hand after the cane is covered, and the cane is rolled in the usual way.

Field and Hay Crops.

Early in the year planters were compelled to buy corn and hay for their mules, due to the severe shortage occasioned by poor crops. A good many of the planters purchased ready mixed feeds. From reports where such purchases

were made, the purchase of the ingredients in the form of corn, oats, cotton seed meal, etc., and preparation on the plantation would have netted savings of from 25 to 30 per cent over ready prepared feeds. This is generally the case, and the attention of planters is called to the savings that can be made in preparing feeds on the plantations.

The growing of hay crops on sugar plantations was undertaken on a large scale in 1920. The heavy types of land which are so uncertain for sugar cane were used extensively for growing hay crops.

Alfalfa was one of the most popular crops. Where the land was well prepared, drained properly and the seed sown in October, good stands of alfalfa were obtained. Longwood plantation in East Baton Rouge reports four to five cuttings per acre, averaging about one ton to the cutting. Other plantations along Bayou Lafourche report equally as good returns.

Sudan grass gave excellent results on Sterling and Glenwood plantations. The seed was sown broadcast at the rate of 20 pounds per acre on twenty-foot beds in the latter part of March and early April. Yields of three to four tons per acre were produced. The hay was found especially palatable for mules and easy to harvest and cure.

Mixtures of alfalfa, alsike clover and oats were also planted early in fall and promises to give good results as an early feed.

Corn and Cowpeas.

Outside of the regular methods used in growing corn on sugar plantations, there was very little progress reported in this line of work. There is a general need of an increased production of corn on sugar plantations, in order to meet the need of providing sufficient corn for working mules. In Iberville parish. Clifton and LeBlanc, on Bellefort plantation, with the use of a mixture of nitrate of soda and acid phosphate, report an increase of about 60 per cent in corn yields The application of fertilizer to corn is one of the corrections that could be made in the old method to increase production.

Cowpeas.

The Brabham variety of cowpeas was tried on a good scale by a number of planters. This cowpea has a very small round seed, which naturally makes one bushel go further than the larger seed varieties. The Brabham compares very favorably with the high class clay pea, and from reports made to the committee it is just as good. The seeds germinate well and produce a heavy growth of vines.

Varieties of Cane.

The variety of D 74 regained most of the popularity it lost in 1919, when unfavorable conditions caused unusually low yields. From the standpoint of the keeping quality of seed cane, D 74 proved its superiority over the native canes. In practically all cases where there were poor stands of cane, the fields were planted with native varieties. In the fall of 1920 acreages of D 74 were increased and the native varieties were planted on a much smaller scale. The only sections where native cane is still popular is in Lafayette and Rapides parishes, where the cane is giving good results.

Louisiana Seedlings.

The work with seedling canes, since the occurrence of mosaic disease in Louisiana, has not made the usual progress. Glenwood plantation at Napoleonville have increased their L 511 cane acreage to about four acres. The following handmill tests were made in November:

Variety	Brix	Sucrose	Purity
L 511	16.47	12.97	78.70
L 253	11.93	7.05	59.2
D 74	14.47	10.93	75.5
Louisiana Purple	14.27	10.27	71.6

In the St. Mary section the following handmill tests were made in October:

Plantation	Variety	Brix	Sucrose	Purity	Acidity
Columbia	L 511	15.43	12.24	79.2	.55
Oaklawn	L 511	14.11	10.61	75.05	.75
Sterling	L 511	16.36	13.69	83.50	.60
Oaklawn	D 74	14.96	11.24	75.05	.55
Sterling	D 74	15.82	12.11	76.30	1.10
Oaklawn	La. Pur.	16.17	13.09	80.90	1.00

L 511 is still promising to give good results, and efforts are being made to increase the acreage of this cane as much as possible.

L 253 and L 231 are giving good results in producing heavy tonnages. Both of these canes have a tendency to mature late, and produced low sucrose and purity juices when analyzed in October and November. A closer study on these canes is necessary before they can be finally rejected or accepted for plantation purposes.

Sugar Cane Borers.

There were a good many complaints of the injuries caused by cane borers in the river parishes and in Lafayette, Iberia, and St. Mary parishes. On Homestead plantation in West Baton Rouge and Southdown in Terrebonne the percentage of borer infestation has been reduced to a considerable extent by planting cane in the fall. From reports received sections doing a lot of spring planting were more troubled with borers.

In the spring of the year Mr. T. C. Barber, entomologist of the United States Department of Agriculture, along with several assistants, spent some time in Cuba collecting Tachnid flies (Pupae) and sending them to Louisiana for release in cane fields. The fly is a natural parasite of the cane borer occurring in Cuba, where it keeps the borer under control. Planters in the State made contributions and the Department of Agriculture co-operated and sent Mr. Barber to Cuba in charge of the work.

The parasitic flies were released on plantations in the State during the summer months. The work of this beneficial insect is being closely watched to see whether they would winter over and propagate satisfactorily. From reports

obtained so far the parasites live through the winter. Care is also being exercised in the way of not burning cane trash where releases have been made, so as to protect the parasites as much as possible.

The committee has endeavored to report on lines of agricultural progress that have taken place in the year 1920. There were a good many general improvements on plantations all over the sugar parishes in the way of repairing and painting of quarters and outbuildings, remodeling and weevil-proofing corn bins, remodeling barns, construction of new sheds and fences.

There has also been a lot of good work done in improving the system of accounting and the keeping of proper records. The successful operation of plantations is so dependent on proper systems of accounting that planters are devoting more time to correcting faults of the old system and introducing new systems that will guide them in their work and prevent them from suffering losses that they have been more subject to with the old systems.

In conclusion, the committee wishes to emphasize the need of more co-operative work on agricultural problems of sugar cane. The American Cane Growers' Association and Louisiana State University Extension Division plan to work more along these lines. The State experiment stations are also joining in the work and are planning to conduct co-operative sugar cane and rice fertilizer demonstrations with planters. Besides this the soil improvement committee will also co-operate in the work. With this plan of work ahead and with the proper interest of planters the work in 1921 should surpass in progress the work of the past years.

Respectfully submitted,

C. B. Gouaux,
J. M. Caffery,
Elliott Jones,
Committee on Agricultural Progress.

[J. A. V.]

Common Sugar Cane, *Saccharum officinarum.**

Natural Order Gramina: nat. both Indies. This plant and its cultivation has been so long known in the West Indies, that it will be needless to say much of it. There are several species cultivated in the Island (Jamaica), which suit the various soils and climates. There are also varieties of this cane both as to size of the joints and colour; some being a yellowish-white, and long jointed, others red and shorter jointed, and another sort Elephantine, with the culm thick, and knots approximate. There is also the Ribbon cane, the culm of which is curiously striped and variegated; but not much esteemed. The Otaheite and Bourbon canes are now very much cultivated, and found to be very productive.

* From Titford, Sketches towards a Hortus Botanicus Americanus, p. 37. (Published in 1811.)

In preparing the ground for planting, the plow is not yet used so much as it might be, and one would suppose with the most beneficial effect. There are ten other species. The virtues of sugar are attenuant, pectoral, vulnerary, and in a high degree nutritious. Muscovado sugar, with Cocoa nut oil, is fatal to worms. A species of wild cane in Jamaica makes an excellent pickle.

[E. L. C.]

The Sugar-Cane; *Lat.* Arundo Saccharifera.†

As it would be more curious than requisite, to examine the several controversial Opinions, whether Canes were originally the Growth of the *East* or *West Indies*; I shall therefore proceed to observe, that in the Manner of their Growth, Form of their Flags or Leaves, and Make of their* Pannicle, they resemble the Reeds which grow in wet marshy Grounds in *England* or elsewhere; however, with this general Difference, that the Sugar-Canes are every Way far larger; and the Inside, instead of being hollow, is full of white Pith, containing a very sweet Liquid. The intermediate Distance between each Joint of a Cane is of different Lengths, according to the Nature of the Soil, Richness of the Manure, and seasonable Weather during their Growth; but in general from one to four Inches long, and from half an Inch to an Inch Diameter, seldom more. The Length of the whole Cane likewise depends upon the above Circumstances. It generally grows to Perfection in about fourteen Months, its then Height (the top Flag-part excluded) is from three and a half to seven Feet, a Medium between both being the most common Length, even in a very good Soil, and seasonable Years. The Body of the Cane is strong, but brittle, of a very fine Straw-color, inclinable to a Yellow. The Extremity of each, for a considerable Length, is cloathed with many long reed-like Leaves, or Blades, whose Edges are very finely and sharply serrated: And the middle longitudinal Rib in each is high and prominent.

F. *Labat,* in his History, says, that there were Canes in the Island of *Tobago,* of twenty-four Feet in Length: If he meant this in general, his Assertion is a strong Specimen of that Vanity, to say no worse, which influences many Writers to be fond of Relations of the marvelous Kind. But whoever judges

† Hughes, The Natural History of Barbados, Book VIII, pp. 244-252. (Published in 1750.)

* There are but few Canes, especially if they grow in a deep Soil, that shoot out into an Arrow decorated at the Top with a Pannicle; and those that do, grow generally in a shallow Soil; tho' the Glumes of their Pannicles contain a whitish Dust, or rather Seed: Yet these, being sowed, never germinate.

The most natural, and perhaps the only proper, Method of producing Canes is by Suckers, or, as Experience shews, with the tender Tops of old Canes: These being cut into Pieces of about a Foot long, and planted in Holes of about six Inches deep, and two Feet wide, and covered with good Manure, each Piece will produce from its Roots a great Number of Canes.

of the Length of Sugar-Canes, in general, from these Instances, if there were any such, may as reasonably conclude from the Height of one *Goliah,* that the *Philistines* were in general of a gigantic Stature.

Whatsoever Difference some Soils, and very seasonable Weather, may occasion in the Growth of this Plant; yet in this all Writers agree, that it is (unhappily for the Planter) liable to one Disorder hitherto incurable, that is, the Yellow Blast.

This, among Diseases peculiar to Canes, as the Plague among those which happen to Men, too justly claims the horrible Precedence.

And as the Ingenious in this Part of the World have not as yet agreed in their Opinions about the Cause of this destructive Blast, I may without any Apology (I hope) offer my own; *i. e.* That it proceeds from Swarms of little Insects, at first invisible to the naked Eye; and as the Juice of the Cane is their proper Food, they, in Search of it, wound the tender Blades of the Cane, and consequently destroy the Vessels. Hence the Circulation being impeded, the Growth of the Plant is checked; and soon after it withers, decays, or dies, in proportion to their Degree of Ravage.

From this Supposition we may easily account for the various Phaenomena, which attend the Blast, whether in its first Appearance, or its further Progress. It is difficult to distinguish the Blast in its Infancy, from the Effect of dry Weather; the Appearance in some Instances seems to be alike: However, the first seasonable Rain manifests the Difference; the uninfected Plant reaps the Benefit of it, thrives and flourishes with great Vigour; whilst the infected, being made more soft and tender by the Rain, becomes easier to be pierced by the devouring Worms. At such and other times, there are often seen, on the Blades of such sickly Canes, many small protuberant Knobs, of a soft downy Substance, often containing in them small white Maggots, which, I believe, turn afterwards into small brownish Moths, which are to be seen in great Multitudes among the Blades of infected Canes. It is likewise observable, that such Blades will be full of brownish decaying Spots: These are so many Places, which have been deeper pierced by the Worms.

Multitudes of Ants are likewise seen on the blasted Canes; these are invited hither to suck the Juice that ouses out of the wounded Leaves, especially when the Plant hath attained any Degree of* Sweetness. This appears by the Clamminess, that, at such times, covers the Leaves, preventing all Perspiration. In this lacerated Condition of the Plant, the Juices want their natural free progressive Motion upwards; the most subtile and finest Part bursting through the wounded Leaves, whilst the more gross returns back unsecreted to the radical Vessels. By this means they are overloaded, and, bursting, supply the Ants at the Roots with a nourishing Liquid. In this injured Condition the Roots become incapable

* Perhaps the Attendance of the Ants may proceed from two Causes: They may be invited, as above-mentioned, when the Canes have attained some Degree of Maturity by the sweet Juice, which ouses out of the Wounds, as may be perceived by the Clamminess of the Blades; or, if this is not the Case, when the Plant is very young, they may perhaps be allured to prey upon the dead and living Bodies of these little Animals infesting the Canes.

of supplying the Stalk or Leaves with Nourishment from the Earth, if the latter should ever recover.

The Blast is observed to be most frequent in very dry Years, there having been but little of it when seasonable Rains have begun early, and continued till the Canes were ripe. In such Years, a great many of these Vermin are perhaps drowned by the heavy Rains, as well as their Eggs made less prolific.

It is observable, that the Blast usually appears successively in the same Fields, and often in the very same Spot of Land: It is therefore very likely, that these are but the successive Offspring of Parent-Eggs, from time to time deposited there by the small brown Moths above-mentioned. And when the Blast is found in Fields of Canes, far from infected Places, we may, in all Probabilitv, conclude, that the Eggs were conveyed thither by the Wind. What makes this more evident is, that the Infection always spreads faster to the Leeward, or with the Wind.

It is remarkable, that if Canes have been once infected with the Blast, although they afterwards, to all Appearance, seem to recover; yet the Juice of such Canes will neither afford so much Sugar, nor so good of its Kind, as if obtained from Canes that were never infected. I conceive that, in this Case, the delicate Strainers, adapted to secrete the Particles, which constitute the Sugar, have been so much injured, as not to be in a Condition to perform their Offices to Perfection, although sufficient to sustain the Plant alive, and in a seeming Vigour.

Should it be asked, If this Blast is occasioned by Worms, how comes it to pass, that the adjoining, and often the intermixt Corn and Pulse should be free from it? it may be easily accounted for from similar Instances in *England*, where the small Worms, causing the Blight or Blast, which destroys the tender Buds of Apple-trees, never affects the Pear or Cherry-trees, tho' in the same Orchard; for, in all probability, neither of these affords a proper Nourishment for them.

Having thus, till better Reasons are offered, shewed the Nature of the Disease, the next Thing necessary will be to look for a Cure.

Hoc Opus, hic Labor est.

Various are the laudable Endeavors to this End, which the Inquisitive in this and the neighboring Islands have made; but, alas! made in vain: Therefore, as this Disease hath been hitherto of the Number of those which are incurable, and almost literally as destructive to us, and our neighbouring Islands, as the Locusts were to the *Egyptians*; a studious Attempt to remove so great an Evil, will, I dare say, meet with the Approbation of every Well-wisher to our *West-India* Islands; especially since what I have to offer upon this Subject is attended with the strongest Probability of Success: And as it requires very little Experience, and less Labour, I may with more Confidence venture to recommend it to the Public.

When the Canes appear to be first infected, which happens generally when they are young, take an equal Quantity of Brimstone, Aloes, and the Bark of bitter Wood; let these be put in the Middle of a Bundle of wet Straw; the Whole must be put in a Cradle of Wire as large or larger than the Crown of a Hat, made Lattice or Net-fashion; this is to be fastened to a wooden Handle of

convenient Length, and kept to the Windward of the infected Bunch of Cane, having first set the inclosed Combustibles on Fire; and holding it there till the thick Smoke hath for some time penetrated among all the infected Blades, and so on to the rest, for a few Mornings and Evenings: This by its very Nature cannot fail of killing those minute Animalcules, as well as destroying those that are in Embryo in those downy *Nidus's* already mentioned. Experience, which is the most convincing of Proofs, gives a strong Sanction to this Method; for we find, that the Smoke of Brimstone, in an inclosed Room full of Flour, pestered with Wevils, will, in a few Minutes, intirely destroy them. If then Wevils, which have a strong scaly Covering, and are grown to their full Strength, can be thus destroyed; how much more probable is it, that such tender small Animalcules may likewise, in the same manner, be destroyed? If it be said, that in the former the Smoke is more confined, it must likewise be considered, that a far weaker Degree of this sulphureous Smoke will destroy Animals of a far weaker Texture, and perhaps of but a few Days old. The Necessity and Use of the other Ingredients of the same Nature are too evident to be further explained.

The Cane-plant being described, and the Diseases of it considered, and a more than probable Remedy proposed, I shall proceed barely to touch on the Method of making Sugar. The* Canes, when ripe, are squeezed between the iron-cased Rollers of Wind-mills, or Cattle-mills. The Juice thus pressed out is boiled first in a very large Copper or Chaldron, mixed with a very small Quantity of Lime. When this is used in too small a Proportion at first, a little Lime-water may be afterwards poured into the Chaldron. A strong *Lixivium* of Ashes will perform the Office of white Lime, and may be substituted in the Room of it; and was originally used, tho' the latter is generally thought to be more efficacious. It is probable, that the Benefits arising from either are, in great measure, owing to their alcaline Qualities. The Sugar-cane, when ripe, is of all other Plants the sweetest; however, there is a latent Acid still lurking in the Juice; this is apparent by its turning sour, if suffered to remain unboiled any considerable Time after Expression. The Addition therefore of *Temper,* as the Planters call it, being a certain Quantity of white Lime, is necessary to destroy, in a great measure, the remaining Acid, and to form a neutral Salt.

That this is one Use of *Temper,* is plain from the different Quantities of that which are used according to the different Qualities of the Cane-juice:

* If, when Canes are ripe, the Weather should prove very rainy, their Juice, if at that time expressed, will require a far longer Boiling, before it comes to the Consistency of Sugar, than if it had been extracted in Weather moderately dry. However, this Difference in the Quality doth not intirely proceed, as it is generally supposed, from the greater Quantity of Water at that time in the Plant, but from the greater Number of newly sprung up Particles, occasioned by the late Rain. These, if soon afterwards expressed, having not had sufficient time to ripen; the Make of their Particles is, as in all Acids, angular, and sharp-pointed, and therefore dissimilar to those ripe ones: They will therefore resist the Heat longer before they are broken, and brought to such a Consistency as to incorporate with the others that are already ripe. From such a Mixture of ripe and unripe Juices, it naturally follows, that the Sugar then made will be neither of equal Consistency nor Goodness with that made in seasonable Weather, and from Canes grown kindly ripe.

That from unripe Canes, as more abounding with Acids, requires a larger Quantity, as doth that also from Canes too ripe, and tainted: For in the latter the acid Salts, that before were neutralized, seem to be again disengaged, and set at Liberty, as may be discovered by its acid Taste. And indeed many Instances occur in making Sugar, which demand an extraordinary Proportion of Lime; all these betray a Tendency to an Acidity in the Juice: But, when the Canes grow kindly ripe, the acid Particles in their Juice are few; and as the Poignancy of these is inconsiderable, the Juice will consequently require a less Quantity of Lime. There is a further Use in Lime, besides the foregoing; for it suits greatly in cleansing the Liquor.

When the Quantity of Lime is duly proportioned, if the Liquor is put into a Glass, an immediate Separation will follow, the Impurities settling to the Bottom, leaving the clear Juice at the Top: But if there is a Deficiency of *Temper,* the Separation will be imperfect: If it too much abounds, there will be little or no Separation at all.

When the Lime is mixed with the Juice in the Copper or Chaldron, the *Sordes* or Impurities, being no longer intimately united with the boiling Liquor, and being forced about with the Heat of the Fire, are easily entangled in a viscous Substance that is naturally in the Cane-juice; and then rise with it to the top of the Copper, forming a thick tough Scum.

This Viscidity is very apparently discovered on the leaden Beds of the Mills, as well as on the wooden Gutters, where the Juice in its Passage deposits it; and its* saponaceous Quality is no less evident in washing the Cloths that have been any ways used in cleaning the Beds of the Mills, or hath any other way been soaked in the Cane-juice.

The Clarification of the Liquor, as far as it is done in the first Copper, is perfected after the more gross Scum is taken off; the remaining Impurity, as the Liquor boils, is skimmed off from the four or five remaining Coppers or Taches, into which the Liquor is successively poured; each of these being gradually less, as they are to contain a Quantity of Liquor still wasting as it boils.

In conveying this to the fourth Copper, it is in its Passage strained thro' a thick Woolen Cloth, where it leaves all the Remainder of its Impurities, that had escaped the Scummer.

After this a light white Scum is taken off; and, when this ceases to arise in any considerable Quantity, and the Liquor, by long boiling, becomes more of a Syrup than a thin Liquid, it is then poured into the first Tache, and from this to a lesser, till it is conveyed to the last. When it hath here attained the due Consistence necessary to become Sugar; it may be asserted in general, that no more than a seventh Part of the Whole remains; which Diminution is occasioned by the Impurities being scummed off, and the watery Particles evaporated.

* This saponaceous Quality in the Cane-juice is capable of resolving viscid Concretions: It is to this, chiefly, that we may attribute the surprising quick Recovery of those sickly Negroes, who are permitted to drink freely of this Cane-juice when intirely ripe. It is likewise so nourishing, that Slaves have subsisted upon this alone for a whole Week.

Repeated Draughts of it are very efficacious, to remove the Effect of the poisonous Cassado-juice.

From this Juice likewise, when mixed with Water, and fermented, is made a Drink, called the Sugar-Drink. This, tho' it appears muddy, yet is very wholesome and diuretic.

From this last Stage, whilst of the Consistency of a thick granulated Syrup, it is conveyed into a large Brass Cooler, where it begins, as it cools, to shoot into Crystals, which are the genuine and essential Salts of the Plant. These are forwarded and helped to shoot, by gently stirring the whole Mass; by which means the Air is admitted to every Part, and the Particles of Sugar disengage themselves from the clammy Substance of the Melasses.

If the Syrup be continued longer on the Fire, than is necessary to bring it to a proper Thickness, the Particles of Sugar cannot grain, or crystallize, when afterwards in the Cooler, for want of a sufficient intermediate Fluid; the whole Mass in such a case being too well united, to suffer the Melasses to separate from it.

On the other hand, if the Syrup hath not undergone a sufficient Evaporation, the Grains or Salts will be larger indeed, but close to each other; Hence several of them being too much separated from their neighbouring Particles, they become too weak to resist singly, and are therefore drained away in the intermediate Fluid, the Melasses. Upon this Principle we may account for the Make of Sugar-candy, whose large Crystals are obtained from a Syrup too thin to shoot into Salts capable of uniting close together.

The proper Time to remove it from the Cooler to the Pots or Moulds, is when it hath grained or crystallized; the better the Sugar is, the sooner this is completed: Hence that just, but ill-expressed Notion, that good Sugar may be potted sooner than bad. The Pots or Moulds made use of are earthen, and of a pyramidal Form, containing from eight to thirteen Gallons.

About twenty-four Hours after the Sugar is potted, the small round Hole in the Bottom of each Pot is unstopped, and the Pots put upon earthen Jars containing about four Gallons, into which Vessels the Melasses drain from the Sugar, the latter becoming fit for Exportation in about a Month's time, and sometimes sooner. The Sugar in this Degree of Perfection is called *Muscovado,* which is a Term too well known to want any further Explanation. What is called here clayed Sugar, is brought to that Degree of Whiteness, by making a Batter of the softest finest white Clay mixed with Water: And after the upper Part of the *Muscovado* Sugar in the above-mentioned earthen Pots is dug up, and closely laid on again in a level Manner, or rather somewhat shelving towards the Middle, a sufficient Layer of this Batter is poured upon the Top of the Sugar in the Pot. The Water from this by Degrees gently ouses from the Clay, thro' the Sugar; and when all the Moisture from the Clay is absorbed by it, which is generally done in about a Month's time, another Layer of fresh Putty is laid on, the former old one being first taken away. In about five Weeks after the latter is put on, this becomes dry, and is taken off; and the Water issuing from it meeting with less gross Viscidities than the former, washes the Particles of Sugar clean, and carries away with it those less feculent Impurities. This completes the Work, as far as it is manufactured here; tho' this is brought to a far greater Degree of Whiteness and Perfection in *England.*

Out of the above-mentioned Skimmings, when mixed with a certain Quantity of Water and Melasses, and fermented, is extracted that spiritous Liquor

called Rum. And from the great Quantity of Oil in the Cane-juice, which is considerably transmitted to the Rum, proceeds the Excellency of this Spirit, when compared with Brandy: The latter, wanting this Oiliness, stimulates and lacerates the Coats of the Stomach; whereas the former, if first meliorated by Age, and made into weak Punch, and drank moderately, by its Oiliness preserves the Bowels.

Most of our Planters are yearly great Sufferers (especially when they first begin to distil) for want of proper Knowledge how to raise and continue a regular Fermentation in the *Mulsa* intended for Distillation: Yet I imagine, that their want of Success may not only be accounted for, but likewise remedied.

In order to do this with Certainty, we must observe, that no Fermentation can be raised under thirty-six Degrees of Heat, or kept up after ninety; a lesser than the former will not be sufficiently warm to raise an Ebullition, and a greater than the latter dissipates the spiritous Particles too much. Therefore if Experiments were made with a Thermometer in every Distil-house, to fix the certain Degree of Heat, that a well-proportioned *Mulsa* would ferment in, it would be easy, by the Help of this Instrument, always afterwards to ascertain this necessary Degree of Heat, let the Change of Weather be ever so sudden or considerable. For if the Heat proved so great as to exceed that Degree, in which such a well-proportioned *Mulsa* was used in Time past to ferment best, then the Windows towards the East ought to be opened so as to admit such a Quantity of cold Air as would reduce the Heat to a proper Standard.

On the contrary, if the Spirit in the Thermometer sinks below the necessary Degree of Heat, then these Windows ought to be intirely or partially shut up, in order to procure a sufficient Degree of Heat. By this means the Distiller may come to a Certainty, and proceed by Rule, and not by Chance.

If after such Rules, and necessary Cautions, the *Mulsa* doth not ferment, if this happens in the Beginning of the Crop; such a Failure ought to be attributed to the then, comparatively speaking, sour and unripe Juices of the Canes: for the Juices of these, as well as most, if not all other unripe Fruits, witness that of the Grape, seldom or never ferment well; because their Particles, in that unripe State, are not sufficiently meliorated by the Heat of the Sun. In such a Case, I am apt to believe, that a greater Proportion of Sweetening, than when the Canes are ripe, should be added to the *Mulsa*.

On the other hand, a disproportionate Quantity of Sweets, as they are Oily, will prove too inactive, and will incline the Liquor more to a Rancidity, than Fermentation: Therefore a greater Quantity of Water, and thin returned Liquor, which hath a great deal of Acidity in it, should be added to the Skimmings of Canes that are full-ripe, and consequently very sweet.

As to those who keep their fermenting Vessels in the open Air, or ill-covered under Sheds, their bad Success may be evidently accounted for, by the Inequality of the Heat and Cold they are exposed to.

I cannot conclude the Description of this very useful Plant, without taking Notice of a most surprising Instance of the Effect of some Effluvia, or Vapours that arose from the Mudgeon or Dregs of the Liquor returned from the Still, and which for some time had been reserved in a Cistern.

In the Month of *April* 1743. *Abel Alleyne,* Esq; the then Manager at the Estate of the Honorable and Reverend Society for propagating the Gospel in foreign Parts, ordered one of the Cisterns, which the returned Liquor was kept in, to be cleansed: The Quantity of this thick Sediment in it was not above seven Inches deep. The first Negro Slave who attempted to clean it, was no sooner at the Bottom, than dead; the second and third met with the same Fate instantly. A white Person, who was a Workman on the Estate, being near at hand, determined, if possible, to bring them up, imagining they were only in a swooning Fit. To this Purpose he went down to the Bottom of the Cistern, which was about nine Feet deep, and found the Negroes dead: He went down a second time with a Rope, in order to fling it about them, and to bring them up; but he had no sooner reached the Bottom, but a sulphureous suffocating warm Blast took away his Senses, and he was taken up for dead; however, being blooded, though he was for a long time afterwards very sickly, yet he at last recovered. The best Method of dissipating these noxious Vapours is to admit into them a free Circulation of the Air, as well as to pour in, by Gutters, a considerable Quantity of Water. This Plant is delineated in Plate XXIII. Fig. 1.

[E. L. C.]

Sugar Cane Seedling Work in India.*

By Dr. C. A. Barber, C.I.E.

PART I.

The present note was first suggested by some queries as to the arrowing of the sugar cane in the South African Sugar Journal of August and September, 1919. The cane does not appear to arrow freely in Natal and a more frequent occurrence than usual naturally led to speculations as to possible seedling work there, with the idea of improving the stability of the Uba cane, which is the main kind grown. Arrows were collected and have been sown and the results are awaited. It is quite possible that this experiment may turn out unsuccessful for, as will be seen, the arrows of members of the Uba class are sterile in India and they may also be so in Natal; but this is no reason why this important work should be given up there, for there are many lines of work open, some of which will undoubtedly suggest themselves to the officers in charge of the experiment stations after reading this account of the Indian work. A further reason for publishing a resumé of the Indian work is that it would appear to be unknown to the workers in the New World, for there is an absence of references to it in recent accounts of seedling work there. This, of course, does not apply to the West Indian and British Guiana publications, in which the foundations of cane seedling work were laid down many years ago, but to places which have more recently commenced to raise seedlings, as in Porto Rico and Argentina, where

* Inter. Sugar Jour., May, 1920, pp. 251-257.


Plate. 23. Page 3
Fig. 3
Fig. 1

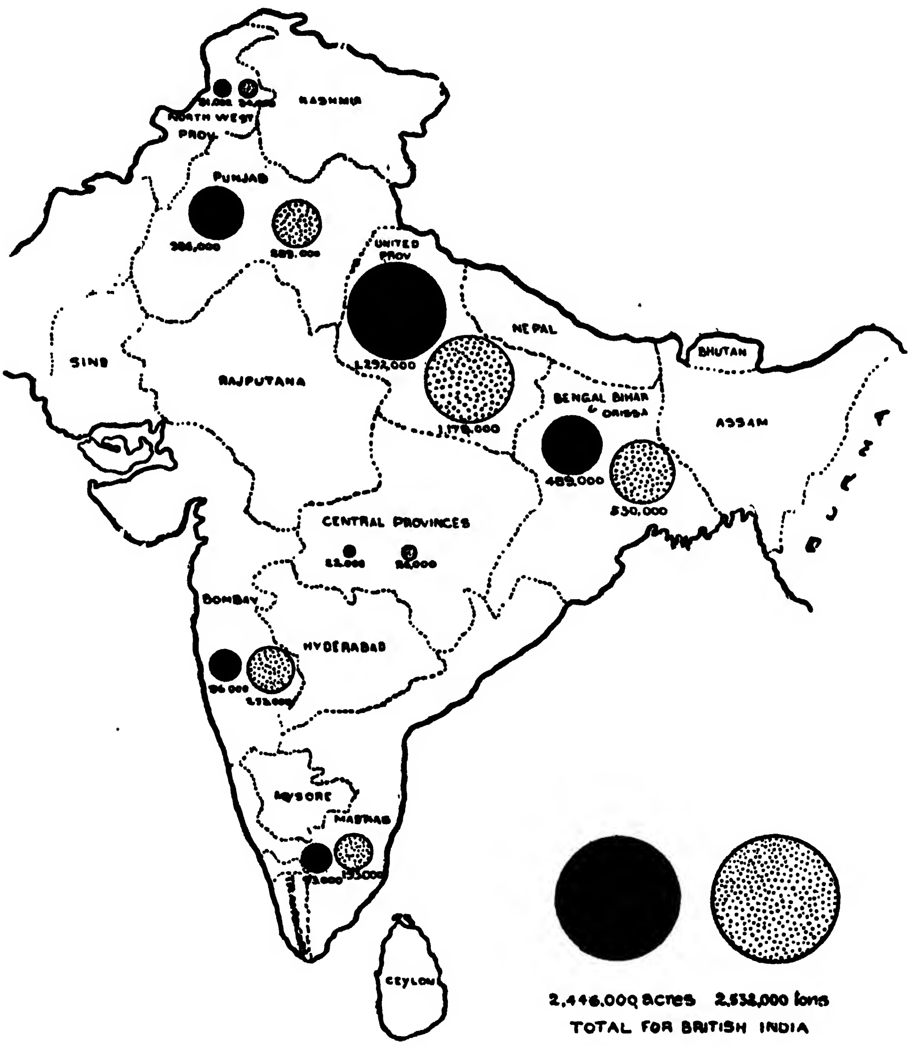
the studies are still in their initial stages. In one respect the work in India, carried out at the Coimbatore Cane-breeding Station, is unique, and that is that it was not a question of merely raising cane from thick tropical parents, but of obtaining definite crosses between these and the many thin, indigenous Indian canes; and not only so, but of obtaining sets of seedlings suited to the very different conditions in the sugar tracts of this great country. This use of Indian canes as parents has greatly broadened the outlook and many facts have come to light which have not been noted in the ordinary seedling work hitherto carried out in different parts of the world. It has, for instance, been found quite feasible to use the wild Saccharums as parents, and some of the children obtained by crossing these with cultivated canes appear to be of high promise, but in vigor and sucrose content, especially for those parts which are liable to injury from frost or drought.

The Possibility of Producing Cane Seedlings in India.

A considerable amount of work has been done on this subject at Coimbatore and various references to it have been published from time to time, but a specially useful article appeared from the pen of Mr. T. S. Venkataraman in a recent number of the Agricultural Journal of India, in which he summarizes most of the work on cane arrowing. The main line of work set for themselves by the officers of the Cane-breeding Station was to produce seedling canes which could with advantage replace the host of inferior kinds grown in the millions of acres of the North Indian sugar tract.[1] When the station was started, seedling canes had not been produced in India, with the possible exception of a few which died in infancy at the Samalkota Sugar Station some dozen years ago. This was not because attempts had not been made, and it was suggested that the extreme dryness of the air might have withered the pollen or ovaries in the flowers. On the appointment of a whole time officer, however, the question was at once taken up. In the Christmas holidays of 1911 a number of arrows was collected and sown in some 300 pans at Coimbatore. A mass of seedlings was soon observed, but most of these turned out to be grasses and, finally, only 11 undoubted cane seedlings were produced. The flowering period was practically past and it was proposed to leave the matter over until the next year, but a study of the inflorescence used showed that most of the stamens were unopened and the available herbarium material was examined to see if there were any kinds in which this was not the case. The flowers of three kinds were found to have open anthers and, after some correspondence, a set of arrows was received from Bangalore of one of these kinds, and was immediately sown, with the result that 50 healthy seedlings were easily obtained. As a result of further study it was found that, when the anthers were open, there was abundance of good pollen present, but when they were closed they merely contained a mass of undeveloped pollen mother cells. The Java test was applied, in which the presence of starch

[1] The relative importance of the two sugar cane tracts of India can be judged by a reference to the accompanying map, reproduced from Bulletin No. 94 of the Agricultural Research Institute, Pusa, 1920, by T. S. Venkataraman, B.A., Acting Government Sugar Cane Expert, Madras.

grains in the pollen indicated fertility and it was found that in every case the open anthers had such pollen while in the closed anthers no starch was present in the pollen grains even if they were formed. Open anthers thus would appear to be the sign of male fertility, and this recalled an observation made some years previously by the writer on the cropping of pepper (*Piper nigrum*) on the west coast. It was noted there, for a vine to bear, it was necessary for open anthers to be present in abundance, and it was also noticed that, once the anthers had opened they remained so permanently, so that the fertility of a plant could be



Map showing the two sugar cane tracts of India.

determined years after in herbarium specimens. This experience was applied to the sugar cane arrows, and the same fact was noted and, in place of the somewhat tedious Java iodine method, the presence of open anthers was taken as the sign of fertility of the male organs. It was at once applied to the arrows in use or received in correspondence, and this was easy, as the examination of the inflorescences could be postponed for months and did not need to be undertaken until the rush of the work during the flowering period was over. Every arrow used

for the production of seedlings was submitted to an analysis, and this has formed an integral part of the work of the station right through; further, every variety of cane introduced on the farm was similarly examined as to male fertility, whether it was used or not, and collections of arrows made from all parts of India where they appeared were also tested. And this collection led to fruitful results, in the following manner. It was found that arrowing was rare in North India and that, when it occurred, the stamens were almost invariably completely closed and no pollen was formed. This explained the former failure to raise seedlings in India, for all of the attempts had been made in Northern India with the solitary exception of the Samalkota one referred to above. Every arrow used on the farm is placed in tissue paper for subsequent examination; 200 stamens are shaken out and these are passed under a hand lens to see which are open, and the stamens are separated into three classes, open, partly open, and completely closed. The results have been kept in a special register. To illustrate the sterility of North India cane flowers the following details may be given of the Saretha variety, one of the few kinds which flower in North India. A set of arrows was received in 1915-16: those from Shahjahanpur (United Provinces), Sipaya and Sabour (Bihar), Jubbulpore (Central Provinces), had no open anthers at all; some received from Pusa (Bihar) had 4 per cent open, while those grown at Coimbatore have habitually over 90 per cent open. The frequency of flowering is illustrated by the following: in 1917, two canes flowered at Shahjahanpur, three at Pusa, six at Sipaya, six at Jubbulpore, 16 in Nagpur (south Central Provinces), 71 at Coimbatore.

Obtaining Crossed Seedlings at Coimbatore.

Large collections were now made of varieties of cane from every part of India, including both the indigenous canes used for gur making and the introduced thicker tropical varieties, grown everywhere but used in the north only for eating as a fruit, as they cannot usually be ripened for sugar making, and some 200 to 300 kinds were got together. But it was found that crossings were not very easy to obtain between these two classes, and the first successful batch of hybrids, obtained in 1912, was between a small North Indian cane and the wild *Saccharum spontaneum,* whose period of flowering is less limited than in cultivated canes. The North Indian canes were shy of flowering at first and, when they did so, it was noted that their pollen was infertile, whereas, curiously enough, the thick tropical kinds formed masses of healthy flowers, from which seedlings could be raised in any quantities here as elsewhere in the world. This raising of seedlings from thick canes was carried out for the first year or two, to obtain better varieties in South India, to gain knowledge on the subject and for the sake of practice, but the aim all along was to obtain crosses between them and the indigenous Indian canes.

The first problem was to make the canes to flower. The North Indian canes were at first obviously out of their element, and it was only later that, by altering their treatment, good healthy plants were obtained. Even then flowering was scarce among them on the farm plots, and a special study had to be made as to the cause of this. The flowering time was found to be strictly seasonal, usually

commencing in October and lasting about six weeks, an unfortunate time for study because this period synchronized with that of the northeast monsoon when over half the annual rain fell, accompanied by storms of wind which rendered the work of manipulating the arrows very difficult. Planting on the station was at the usual time, February to March, and the canes were reaped a year later, no arrows being formed. But it was found that, if the canes were planted in November, they flowered in the following October. Hence a series of "arrowing plots" were laid down, plant canes and first ratoons, and this part of our difficulty was solved. There are two classes of sugar cane land at Coimbatore—"dry," of a lighter nature and irrigated from wells and then termed "garden land," and "wet," very heavy clay irrigated for many years from tanks. The wet land had been created from the dry by this perpetual irrigation, through which the finer clay particles had accumulated during many years. It was noted that, in the wet land, canes planted as late as March or April would generally flower in October, and thus much of the earlier work was done with arrows collected from this source. The cane farm was chosen deliberately on the dry land, because this was more in keeping with the land of the sugar cane tracts in North India. The following figures of thick and thin canes flowering show the results obtained in our efforts at causing the canes collected on the farm to flower. The first figure in each year is of thick cane varieties and the second of thin:

1912, 3, 0; 1913, 0, 0; 1914, 5, 4; 1915, 35, 36; 1916, 62, 34; 1917, 83, 52, besides among our own selected seedlings, 183, 103.

The Effect of the Weather on Flowering.

It was soon noted that the mass of flowers produced was very different in different years, and a study of the rainfall showed that this was a factor of some importance. In North India the arrowing of the sugar cane varies a great deal, being rarer and rarer as the Punjab in the northwest is approached, and there it is unknown. In certain tracts it is recorded that the appearance of the arrows in the cane fields is regarded as a grave portent and whole villages are said to have been deserted from this cause, for fear of the drought and famine which followed in its train. Flowering is common in the Peninsula, but is much more abundant in the drier, western than in the moister, eastern regions. At Coimbatore, itself in a semi-arid tract, it was found that good rains during the growing season had a markedly beneficial effect on the number of arrows appearing. The wet land showed plenty of arrows and, on the farm, it was found of advantage to place the arrowing plots on places liable to be flooded in the rainy season. Here, then, we have two opposing views as to the effect of the weather on arrowing, and it is somewhat difficult to reconcile them. If we might hazard a solution, flowering is probably aided by some interference in the normal progress of growth, some check, whether from drought or waterlogging, and this is in general agreement with a practice in horticulture, for instance, in making azaleas to bloom freely by introducing them into pots too small for their free growth or in injuring fruit trees to make them fruit more abundantly. It may be noted that the reports from Natal indicate that the Uba cane flowered abundantly in places where the rainfall was deficient, thus falling into line with the North Indian experience.

We thus see that arrowing of the cane in India is affected by latitude, by the time and planting and by the character of the soil and its treatment, while the usefulness of the arrows for the production of seedlings depends in the first instance on their possession of abundance of opened anthers. Although enough data have not as yet been accumulated for clearing up the matter thoroughly, it is evident that the amount and character of the rainfall also have a direct effect. As we shall see later, the habit of flowering is a character of some importance in classification, the greatest diversity occurring among different canes in this respect.

The Determination of Female Fertility.

This is by no means an easy matter, and we have usually had to record the previous behavior of each variety in order ultimately to form an estimate of the chances of obtaining seedlings when using it as a mother. And we have learnt from our experience that the arrows vary as much in this particular as in the fertility of the male organs. Working along these lines it occurred to Mr. Venkataraman that the presence of starch grains, which had proved so useful in determining the fertility of pollen in the sugar cane, might also be shown in the stigma. This was proved to be the case, as far as the very extensive trials at present made can be taken as a guide. If the stigma and style have starch grains in them the probability is that the flowers are capable of producing seed and seedlings, but if there is no starch the chances are against it. This important discovery has lightened the work of crossing at the Cane-breeding Station very considerably of later years, by the avoidance of large numbers of crossings which would turn out useless, and concentrating on such as would, other things being equal, turn out successes.

Variations in the Time of Flowering.

Having thus at length obtained an abundance of arrows from different varieties of canes on the station, the path of progress was arrested by the annoying fact, which soon obtruded itself, that, within the limits of the season, the different varieties had their own particular time of flowering. The thick canes as a class flowered earlier than the thin; when the latter opened their flowers, most of the thick canes had faded or were at any rate past their prime and more or less useless for crossing. The following will give some idea of this phenomenon. Among the thick canes, Vellai, with often almost entirely closed anthers, leads the way, its flowers opening during the second and third week in October; Karun, Chittan and Kaludai Boothan follow; then D. 74, Mauritius 16 and Java and, in the middle of November, Pachrangi and Moradabad. The thin canes are led by the Pansahi group, also generally devoid of open anthers, at the end of October, then the Saretha group commences flowering, and these are followed by the Nargori and Mungo groups. It thus happens that Vellai with its male sterility is over before the Saretha group comes in with its masses of fertile pollen, whereas the Pansahi group is obviously useless for this crop because of its own male sterility. These and similar difficulties have constantly hampered us in our efforts at obtaining the much desired crosses, for a good mother, that is one that has no good pollen, is rare and obviously of great value. There is some

evidence that in many cases there is prepotency of the pollen in its own flowers and, in numberless experiments of dusting foreign pollen on arrows with male fertility, no trace of the foreign blood has been observable, although it is only fair to say that important exceptions occur and the method has its value. In these circumstances we have turned to whatever arrows were available, and there is one set of our seedlings which has been of the greatest service. It has all along been observed that, in every large batch of thick cane seedlings, a very small proportion show remarkable differences from the usual type. These seedlings have strange forms, quite unlike the parents or any cane growing on the farm; they are immensely vigorous but have low sucrose content, are in fact in some respects more like the indigenous Indian canes than seedlings of thick canes. They have the power of producing masses of flowers which are specially fertile, yielding great numbers of seedlings, and which when selfed show no approach to their thick ancestors but remain true to the new type. These we have called "rogues." They differ from the other canes growing, in that they flower early, and are thus available for crossing with Vellai and indeed most other thick canes as mothers. It was at first thought that they might be accidental crosses between the thick and thin canes, but they have again and again appeared before any of the latter are in flower. And a similar use has been made even of the wild canes, which are less strictly limited in their periods of flowering. Thus *Saccharum Narenga* begins to flower a good deal earlier than Vellai and continues so to do throughout the flowering season, and a fine series of crosses were obtained between these two. Narenga is a grass and does not form a solid cane, and the crosses show canes varying from one to six feet in length (Plate I). But all attempts to make further use of these seedlings have been unsuccessful for, although they are profuse in flowering, they are absolutely sterile both in the male and female organs. The difference between the parents in this cross is too great, and they are apparently all of them "mules." But by crossing Vellai with *Saccharum spontaneum* some very useful seedlings have been obtained, certain of them sent to the Punjab giving a very good account of themselves. Meantime, the most various devices have been adopted to retard the early flowering of the thick and hasten the late appearance of the thin canes, with the result that some of the latter have been hurried up, and a number of crosses formerly unobtainable have now been secured.

Degree of Development of the Arrows in Different Canes.

The different varieties and groups of canes show great diversity in this respect, more so indeed than in the times at which they flower. We have all stages, from some which have never been known to arrow and have not done so with us, through those that are beginning to yield to treatment and up to such as readily produce masses of fertile flowers on the least provocation. The fullest development of arrows is found, somewhat strangely, in various highly developed thick canes, as well as the most primitive class of the Indian indigenous ones, these forming the extremes in sugar cane evolution. The latter are typical of the Punjab and it is fairly safe to say that most of these have never flowered since they were first introduced to cultivation there, for canes have, I believe, never been known to flower in the Punjab. While it is natural to sug-

Plate I. Vellai x **Saccharum Narenga** (1913-15). Canes of parents and seedlings.
5.—Two Vellai canes. 6.—**Saccharum Narenga** "Canes." 7.—A selection of the canes of the resulting crosses, from the thickest to the thinnest, one average cane from each of **six** seedlings.

gest that this readiness to flower in these primitive canes may be connected with their nearness to the wild state, this cannot be assumed with regard to the rich and highly developed forms which show equal readiness to flower. Many of the North Indian canes have been induced to flower on the farm for the first time within knowledge, some of them it is true in a very half-hearted way, but it is legitimate to hope that, with further study, the tardy and at present infertile members may some day produce flowers which will add to the range of our crosses. Each such form has some good points, whether in erectness, or short and sturdy habit, self-cleaning or drought resistance, and it would be of advantage if these could be added to our list of useful characters in the field.

The great Saretha group heads the list in producing masses of flowers from which any number of seedlings can be raised; the group has, however, its defects. Its members are liable in a greater or less degree to be infected by smut, and this is a very serious disease in certain important sugar tracts in North India. It may be noted that some of the Java seedlings with a male parentage of members of this group are similarly liable to smut. A second fault, shared it is true by others, is that the selfed seedlings are as a rule of very inferior character, many of them mere tufts of grass; one indeed was found crawling along the surface, with stems 20 feet in length and the thickness of a lead pencil, and never raising themselves off the ground. The seedlings thus far raised have juice very inferior to that of their parents. In one year 700 strong seedlings were raised by selfing Saretha, the type variety and perhaps the best all round variety of the group. These were grown to maturity in the vain hope of obtaining one or two which had good habit and juice of a better purity than that of the parent, but nothing was gained by the experiment. The Sunnabile group flower sparsely, and very few of them produce seedlings. The varieties of the Pansahi group, of which Uba is a member, produce enormous masses of beautiful large arrows but, as a general rule, these are made sterile and hitherto the crosses have not been of special value, excepting perhaps in general vigor and good habit, in which character they resemble their Pansahi parent. The juice is usually not good as far as I remember. In the Nargori group the arrows are deformed and the flowers ill-formed, often only half protruded. The Mungo group does not appear to be likely to be of much use in crossing, much as this is to be desired; the arrows when they are formed rarely protrude from the sheaths, forming inside the merest rudiments of flowers. In the thick cane group, there are all stages from complete sterility to abundant seedling production, and, in the latter case, all stages of robustness have been noted. In one case out of 4000 apparently healthy seedlings it was only possible to raise two, although the greatest care was taken of them in all stages. A mass of information can be extracted from the carefully kept office registers in the Cane-breeding Station on these and similar points. All attempts at selfing good seedlings have been given up, on account of the generally inferior nature of the resulting second generation of seedlings. The arrows of different kinds of cane are often very different in form as well as in fertility, and this fact has been of use on several occasions in disentangling the different arrows where the kinds have been growing close together in a crowded field. Several errors in classification have also been cor-

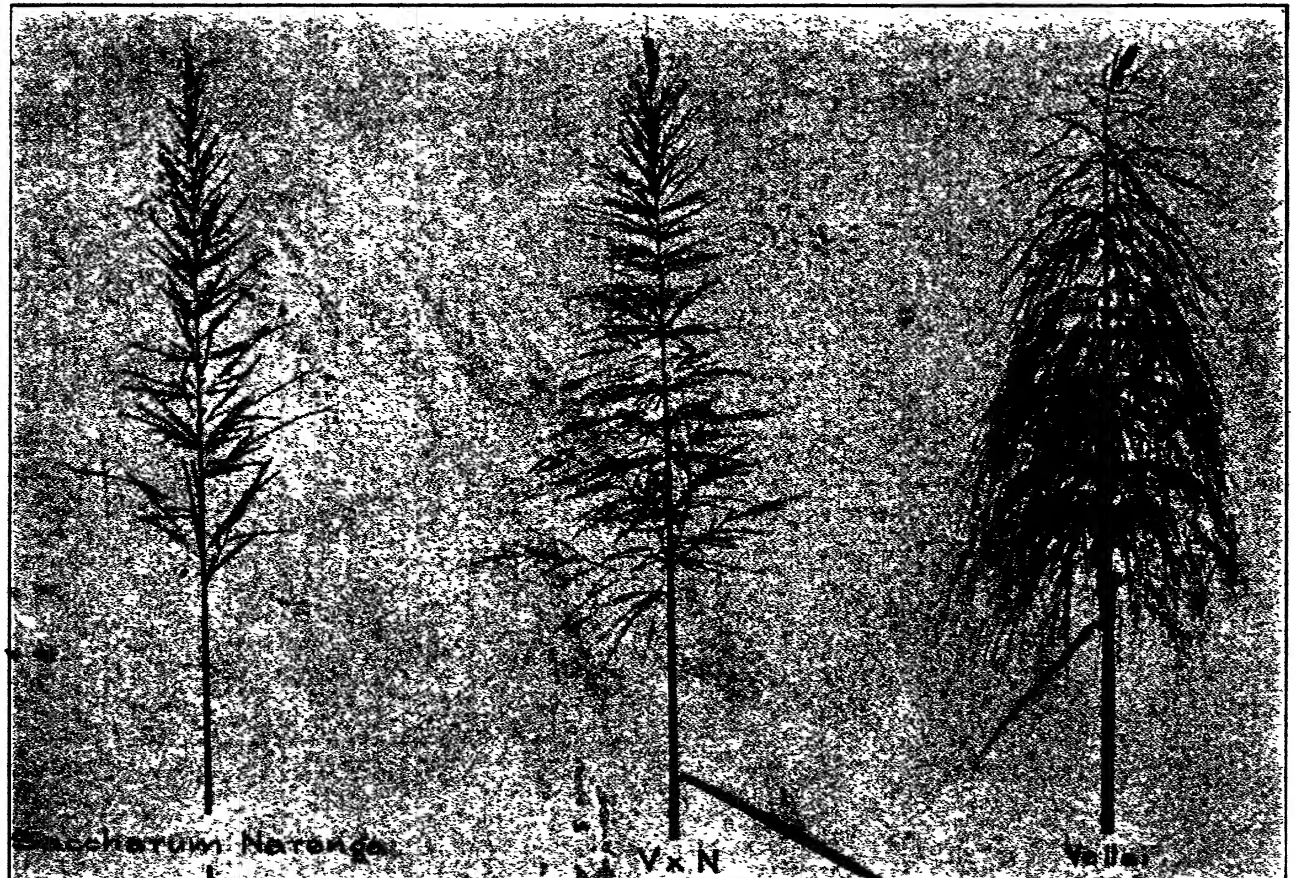


Plate II.—Vellai x **Saccharum Narenga.** Arrows of the parents and of a typical cross.

rected by noting the time of protrusion of arrows and their form when protruded. Perhaps the most interesting case of these differences is that met with in the crossing of Vellai by *Saccharum Narenga,* where the arrows of the seedlings are obviously in many respects half-way between the very different ones of their parent. This is shown in Plate II.†

[J. A. V.]

German Potash Mines.*

THE POSSIBILITY OF FINDING POTASH DEPOSITS IN THIS COUNTRY.

By Robert G. Skerrett.

Potash in the decades gone, when soft soap was a common commodity in the household and not the synonym for conversational blandishments, was generally got from wood ashes subjected to a simple leaching process. The very term potash is a word picture of the way in which the alkaline liquor was boiled down and concentrated. At that period in our development, potash so obtained served as an essential ingredient not only in the preparation of a laundering aid, but it figured in the manufacture of glass, powder, etc. Farmers knew that their crops were likely to be more abundant if they burned over the dry vegetation of their fields or scattered wood ashes broadcast upon their acres; but only a few husbandmen were aware that a measure of potash was indispensable to their crops and needed proportionately more by some than by others.

Potash, or potassium as it is technically named, has assumed a position of prime importance in the economy of modern life far beyond that imagined half a century ago. Not only is the stuff required in the making of glass, as a source of nitrate in the explosive industry, and as a base for cyanide so widely employed in metallurgical activities, but the sulphate and the chloride of potassium are outstanding factors in the manufacture of so-called artificial fertilizers. Finally, to a lesser degree, but likewise invaluably, potassium salts are used in dyeing, tanning, electroplating, photography, medicine and as chemical reagents for a variety of purposes.

Just what potash means to us can be gathered from the fact that up to the outbreak of the World War we imported from Germany, our principal foreign source of supply, substantially a million gross tons of the salts each twelve months; and probably about 90 per cent of that material was devoted to the enriching of our cultivated soil. There are three plant foods of outstanding significance—phosphorus, nitrogen, and potassium, and the last serves to promote stalk strength and a more generous kernel filling in a growing plant. Fields

† Plates I and II are reproduced by kind permission of the Agricultural Adviser to the Government of India, from C. A. Barber, "Studies in Indian Sugar Canes," No. 2. Memoirs of the Department of Agriculture in India, Botanical Series, Vol. VIII, No. 3, July, 1916.

* Scientific American Monthly, Feb., 1921, pp. 151-154.

denied a sufficient quantity of potash yield crops of an impaired and sometimes an unmarketable character; and the best proof of this is what happened in our farming districts when cheap potash from the mines in Prussian Saxony was cut off from us by reason of the conflict in Europe.

According to testimony given before a Congressional committee in 1919, the lack of potash had a serious effect upon our cotton, potatoes, onions, citrus fruit, and garden truck, and this largely because the commodities were deficient in that strength needful to enable them to withstand transportation and to keep them fit until sold. As one prominent farmer from the South explained it, "If there is not enough potash in the soil, I get a plant that is so sappy and tender that it won't bear transportation. And to get that plant sufficiently woody

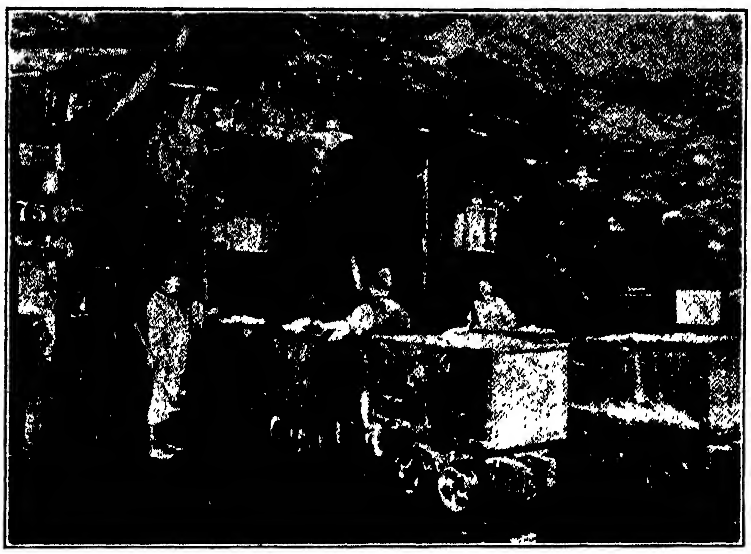
In the heart of a potash mine at Stassfurt 2600 feet underground where temperature is 104 degrees F.

and strong to bear a long trip we have to use from 10 to 14 units of potash per acre." A unit is 20 pounds of pure potassium oxide. Time and again, peaches, strawberries, cabbages, beans, cucumbers, etc., which appeared all right when picked, would spoil or fall below standard by the time they reached a far-off city; and that in spite of refrigeration en route. Ground that would ordinarily give a crop of 80 barrels of potatoes to the acre would yield only 11 barrels and even then the tubers were not up to the usual size.

With cabbages, potatoes, and onions constituting the principal vegetable items of the dietary of the vast majority of our people, and with cotton forming the fiber for that textile used in such vast quantities by both the rich and poor of the nation, it is not hard to visualize how vital to our well-being is an abundance of low-priced potash. When the German potash deposits were first exploited sixty-odd years ago, and the mining of those beds proved a simple and fairly inexpensive operation, the agricultural world breathed freer; for the geolo-

gists proclaimed that there was enough of the alkali tucked away there under ground to meet the demands at home and abroad for centuries to come.

These mines are located near Stassfurt, and were discovered by the Prussian Government in 1843 while boring for rock salt. For some years no attention was paid to the potash, which was brought up to the surface and cast aside. But afterwards, when it was found that potash was essential to the stimulation of crop production, the value of the neglected piles of mine waste dawned upon the Teutons; and out of that awakening developed the well-known Kali Syndikat which became all-powerful in the international distribution of those potassium salts. This was made possible by the fact that the Germans could mine, ship across the ocean, and deliver the potash at the ports of our Atlantic seaboard at an average price of from seventy to eighty cents per unit of pure potassium.



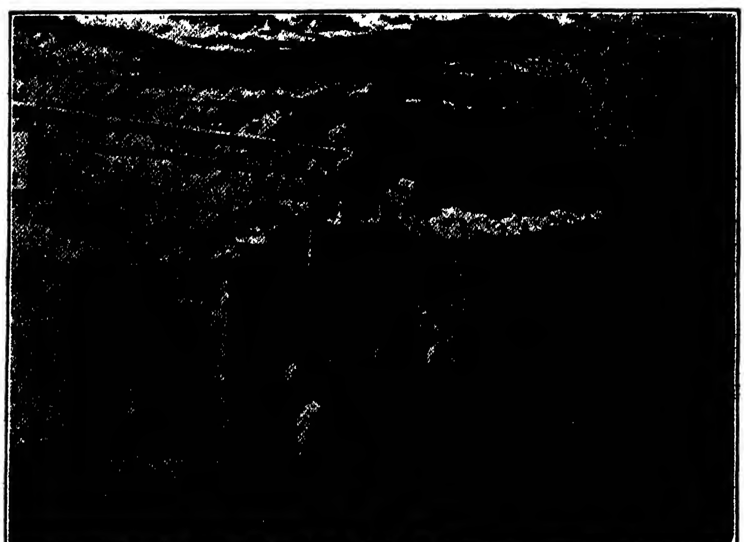
Loading an elevator at the bottom of a shaft 2500 feet below the surface.

The Stassfurt salt beds, with their interposed layers of potash, were deposited there in the Quaternary Age of this globe of ours, when the present plains of northern Germany lay deep beneath a briny ocean. In the course of time, using the term in the ampler geological sense, the potash separated from the salt and was precipitated in the form of strata or pockets. This process has a great deal of significance to us in view of the fact that vast deposits of salt, likewise the relics of a sea that evaporated eons back, lie far below the ground level in a widespread area extending north and south throughout certain of our Central States. A similar condition probably exists elsewhere upon this continent of ours; but the revelations in question have been made by borings driven in search of petroleum.

In 1914, prior to hostilities, the German potash industry at Stassfurt was centered about 187 shafts, and the operating force numbered 35,000 people. It is said that quite $250,000,000 has been spent in developing the properties, and that the mines are capitalized at substantially $380,000,000. An official of the U. S.

Bureau of Mines has lately visited the region and has reported that the "Stassfurt potash occurs as potassium chloride or potassium sulphate or both salts intimately mixed with salts of sodium, magnesium and lime, and contaminated with substances insoluble in water, such as ferric oxide, clay, etc. The potash salts are segregated in more or less extensive pockets throughout the salt mass. * * * The main potash region is a stratum varying from 30 to 150 feet in thickness and at a depth requiring shafts of 5000 feet." It should be evident that the raw product is of a mixed nature, and when sold as such is valued according to the percentage or number of units of pure potassium which the stuff contains. On an average this is in the neighborhood of about twelve per cent of pure potassium.

According to the German laws, each mine must have at least two shafts—one for ventilation and one for active operation. These shafts are placed from 500



A train of cars or buggies loaded with potash drawn by an electric locomotive.

to 1000 feet apart and are connected underground. This arrangement insures that the air drawn down one shaft shall, after circulating through the several mine passages, ascend by the other shaft and thus carry off the vitiated atmosphere. The duplication of shafts further provides a means of escape for the workmen in case one of the shafts is closed by accident. It is the practice to line the shafts from top to botom with iron, concrete or wood, according to the local needs and the availability of the materials mentioned. The shafts average about 16 feet in diameter.

As might be expected, water reaches the shafts by reason of seepage working through at the upper levels. This water drains down into sumps at the foot of the shafts, whence it is forced surfaceward by pumps. The mines are otherwise dry. Because inflammable gases appear only infrequently, the miners work by the light of bare flames, using generally a rather common type of acetylene lamp. The danger of unexpected gassing is neutralized by the action of

blowers, which are kept running close to the points where the men are at work. The potash is blasted out at the face of the headings and freed in this manner in big masses. The needful holes for the explosive charges are made with electric drills and augers. The material is then broken up by the miners into good-sized lumps—using picks and heavy hammers for the purpose. At the same time the laborers separate the low-grade material for that of commercial value, and the rejected stuff is used, as occasion requires, to fill up abandoned workings.

The potash is transported from the headings by electrically-drawn trains made up of small iron cars or "buggies," and moved by rail to the elevators located in the shafts. These lifts are functioned by a mechanical contrivance that insures a nice control of their speed. There are two counter-balancing elevators in a shaft, and this interrelation has much to do with the safety of their service. Each lift is a double-deck structure which can accommodate from six to eight of the mine cars; and when working to capacity it is practicable to send to the surface between 800 to 1000 tons of the raw potash daily by way of a single shaft.

Upon arriving above ground, the buggies, with their burdens, are run upon a platform where they are caught and held while being tipped over to effect discharge, and the crude salt drops by way of a chute into a power-driven crusher located below. From the crusher the substance may be dealt with in two ways, i. e., it may be ground into bits, having a maximum dimension of a quarter of an inch, and then removed to storage awaiting shipment, or the granular material may be sent to a refinery, frequently nearby. Here, trained operatives sort out further the relatively high-grade from the low-grade potash. The latter is passed on to a grinding mill, where it is mixed with raw salts, and the better grade is carried to another grinding mill and from it dropped into an elevator that transports it to the storage bin preliminary to undergoing additional treatment.

According to the report of the representative of the U. S. Bureau of Mines, who visited the European mines, analyses showed a raw salt averaging 15.6 per cent potassium oxide, while the rejected or low-grade material contained 5.8 per cent K_2O. As he explains: "The latter being added to the raw salt or 'stock kainite' brought its potash content down to 14.3 per cent, while the rich salt for the refinery was brought up to 18.6 per cent K_2O." The procedure in the refinery rests on the fact that if a solid mixture of the chlorides of potassium and sodium be brought in contact with a saturated solution of the same salts, and the combination be then heated, this treatment will induce the precipitation of a greater amount of solid sodium chloride and effect the while a further solution of a considerable percentage of potassium chloride. By properly handling thereafter the masses of brine and solid salt it is feasible to accomplish the complete recovery of the potassium chloride in any desired degree of purity.

The actual working of the process commercially is as follows, according to the authority just cited: The rich salt, so called, is fed into one end of a trough, made of sheet iron, and the boiling-hot brine enters at the other. The trough is fitted with a screw device which thoroughly stirs the mass and gradually drives the solid contents toward the opposite end of the trough and against the oncoming flow of the liquid. The trough is equipped with steam pipes which

enable the temperature of the mixture to be raised as high as 230 degrees Fahrenheit. The solids in the trough or dissolver are removed by a screw-like elevator, washed, drained, and piled, until sufficiently air dried, when they are either returned to the mine to fill abandoned passages or are sold for crude sodium chloride. The washings are added to the mother liquor and used for subsequent dissolving operations. The hot brine from the trough is led to settling tanks, where the temperature falls slightly below the boiling point, and the somewhat clarified liquor is thence siphoned to the crystallizers. The residue in the settling tanks is drawn off, and drained more or less imperfectly, and the drippings are added to the mother liquor—the solids, for the most part clay, being discarded. The residue, amounting to from 6 to 8 per cent of the product as it comes from the mines, carries probably 1.5 per cent of potash. It seems that the loss of potash in the residue is but little more than 1/10 of 1 per cent.

Crystallizers are nothing more pretentious than flat iron boxes about 2 feet

Calcining ovens in which the potash salts are thoroughly dried out.

deep and large enough to hold approximately 6000 gallons of the brine solution. Three days are commonly required to bring the temperature down to 50 degrees Fahrenheit. Each "pan" will yield better than 3 tons of crystallized potassium chloride; and a plant equipped with 72 crystallizers, working in three groups of 24 units, will turn out an average of 80 tons of finished salt every twenty-four hours. The mother liquor is used over and over again. The Germans have done this for 12 months' running—discarding the liquid only when it became too highly charged with magnesia and other impurities to make it serviceable. For a plant of 72 crystallizers, the coal burned, exclusive of that for the generation of electric current, has been at the rate of 13 tons per day in the refinery, and probably about 7 tons additional for general purposes in the mine, the plant, and office.

The potash deposits in Alsace, which are now in the hands of France, were

only moderately exploited by the Germans prior to the World War, and they were tapped by but 17 shafts. The beds were discovered six miles northwest of Mulhouse, as recently as 1904, during exploratory borings for oil. The first mining shaft was completed in 1909 and production started in 1910. In 1913, 40,707 tons of K_2O were procured from that source. The Alsatian deposits differ notably in physical and chemical characteristics from those in Saxony. The lower layer lies at an average depth of but 1800 feet, and constitutes a fairly continuous stratum, composed of a mixture of potassium and sodium chloride, extending over an area of upward of 77 square miles and having a mean thickness close to 11.5 feet. Twenty feet above this layer is a parallel but less extensive bed, ranging 4 feet through. Both beds are pretty commonly banded with blankets of clay, and these vary in thickness from a fraction of an inch to several inches. The upper deposit is deemed less important, and is looked upon as a reserve which can be worked later on. The volume of the two layers is estimated to be 1,350,000,000 cubic yards, calculated to contain in the neighborhood of 1,500,000,000 tons of salt or 275,000,000 tons of pure oxide of potassium—enough to meet the world's demands for possibly two centuries. The Stassfurt beds, on the other hand, are said to contain fully 2,000,000,000 metric tons of K_2O—sufficient to meet man's requirements for 2000 years at the normal rate of consumption.

The World War brought America face to face with the possibilities of a grave potash shortage. The year before the outbreak of hostilities our importers were paying less than $90 a ton for pure potassium oxide, and before the close of 1917 domestic potash, at the plants of fertilizer manufacturers, was fetching $560 a long ton! This was derived from original sources such as alunite, the brine of certain of our highly alkaline lakes in some parts of the country, kelp, and as a by-product of the cement industry, from wood ashes, molasses distillery waste, beet sugar refineries, etc.

By dint of very commendable enterprise and outlays totalling, so it is authoritatively declared, substantially $40,000,000, patriotic citizens embarked upon the upbuilding of a domestic potash industry. The natural salts or brines from Searles Lake, California, and the lakes in northwestern Nebraska, were the principal origin of the much-desired potash obtained here after we were thrown back upon our own resources. In 1918, it was from Nebraska that we secured approximately 60 per cent of the potash produced within our borders. The section is known as the sand-hill district of Nebraska, where foliage is commonly lacking, although the soil in the valleys is fairly well cloaked with a growth of grass.

Within that region lie, in round numbers, 3000 lakes ranging in size from modest ponds to bodies having an expanse of 600 acres. The depths of these waters run from 1 to 6 feet, and virtually 10 per cent of them are decidedly alkaline, and fully 150 of these ponds and lakes carry a high percentage of potash. The richest brines are in the bed mud and sands, and these extend downward for from 15 to 40 feet. The brines are readily obtained by pumping operations. The productive area beneath the several lakes differs greatly. That is to say, it has been found to underlie a large part of some lakes and yet, as a rule, only

a small proportion of the subsurface sands have yielded brines in commercial quantities.

A very significant feature in connection with these Nebraskan fields has been the results realized from a few wells sunk in valleys more or less distant from the lakes. The quality of the brines brought to the surface have suggested that the productive region may possibly reach far beyond the lakes themselves and may even exist in localities where there are no lakes at all. Nineteen companies have operated in Nebraska, and during their activities developed capacities ranging from 3 to 200 short tons of crude potash salts daily. Inasmuch as the total quantity of potassium in these beds is rather speculative, their potential value cannot be determined. However, one investigator has put the recoverable underground supply at 100,000 tons of K_2O.

From Searles Lake, California, we secured the second largest output of domestic potash, viewed as a single source, in 1918. The production was nearly double that of the year before; and the salts contained from 60 to 70 per cent of potassium chloride and about 15 per cent of borax. In the process of manufacture, after recourse to partial evaporation to remove a part of the associated salts, the brine is drawn off and allowed to cool—this procedure serving to precipitate the marketable potash. Estimates seem to indicate that Searles Lake contains the equivalent of 20,000,000 tons of actual potash in a saturated brine associated with soda, borax, salt, and sodium sulphate. The proportion of potash in the dried salts is about 7.2 per cent. In the German and Alsatian deposits the K_2O content ranges from 12 to 20 per cent.

Potash obtained from alunite in 1918 amounted to 6180 short tons, containing 2621 tons of potassium oxide, then valued at $1,276,774 at the point of shipment, i. e., $4.87 per unit of K_2O. The entire output was derived from the alunite deposits in the vicinity of Marysville, Utah. Unfortunately, the quantity of alunite available for potash is not known. From such of our cement mills as are equipped with potash recovery plants we secured, in 1918, 12,652 short tons of crude potash, containing 1549 tons of K_2O. And from our blast furnaces and silicate rocks we got a matter of 310 short tons of potassium oxide. Kelp supplies us with 4804, molasses distillery waste 3467, beet sugar refineries 1374, and wood ashes 673 short tons of K_2O.

What store of potash may still be hidden underground in the United States is quite unknown, but inasmuch as potash is associated in Alsace and Saxony with the salt beds of prehistoric seas, there is ample reason to believe that similar occurrences here may be indications of a like if not a greater wealth of subterranean potassium.

Doctor George Otis Smith, Director of the U. S. Geological Survey, has said: "We have been searching for potash on a very small, even a picayune, scale. For instance, there may be and probably are certain points in our underground deposits of salt where conditions were favorable for potash to be deposited. We have put down one hole in an area of 98,000 square miles, which is like taking just one look in a hay mow for a missing needle."

[H. v. I.]

SUGAR PRICES FOR THE MONTH

Ended May 14, 1921.

		96° Centrifugals		Beets	
		Per Lb.	Per Ton.	Per. Lb.	Per Ton.
Apr.	19, 1921	5.635c	$112.70	No quotation	
"	21	5.325	106.50		
"	22	5.02	100.40		
"	26	4.89	97.80		
"	27	4.88	97.60		
May	4	4.64	92.80		
"	5	4.6167	92.334		
"	9	4.76	95.20		
"	10	4.89	97.80		
"	11	4.885	97.70		
"	14	5.02	100.40		

[D. A. M.]